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ABSTRACT

This syllabus is divided into three sections and three appendices. The first section lists program objectives with corresponding performance criteria for seven areas of weather/climate study: (1) broad-scale weather systems; (2) local weather; (3) the atmospheric environment; (4) energy and motion in the atmosphere; (5) water in the atmosphere; (6) hazardous weather; and (7) climate. The second section lists science processes numbered from 1 to 23. The third section provides lists of concepts and understandings for each of the seven areas of study together with suggested questions and activities. Activities in this section (indicated by a letter/number combination such as E-32) are keyed to one or more of 62 learning activities presented in appendix A. Instructional strategies are provided for all activities in this appendix; in addition, each activity is keyed (by number) to the science processes listed in section 2. Appendix B contains charts, tables, and diagrams for selected activities. These include weather information and temperature/pressure charts, a wave cyclone model, a model data sheet for weather watch, and a wind chill table. Appendix C contains supplemental teacher information on weather/weather systems, weather models, satellite images, and hazardous weather. (JN)

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FOREWORD

This publication is the sixth product of the project to significantly update and reorder the Science Syllabus for Middle and Junior High Schools. The project will result in a group of instructional blocks encompassing the content and skills in the biological, physical, and earth sciences appropriate for those grade levels.

The understandings, questions, and learning activities in the publication have been enhanced by the inclusion and referencing of program objectives, performance criteria, and process skills which serve to focus student achievement. The content also addresses life survival understandings associated with severe weather phenomena.

The objectives and performance criteria are provided in a general outline on pages *iv* through *vi* which conforms to the content subdivisions in the publication. Process skills are keyed to the learning activities, and the learning activities are keyed to the understandings and the questions.

The materials were prepared by Dr. Ira W. Geer, Professor, Department of the Earth Sciences, State University of New York College at Brockport. Douglas S. Reynolds, Chief, Bureau of Science Education and Barry W. Jamason, Associate, Bureau of Curriculum Development coordinated the development of the syllabus. The entire manuscript was reviewed by Thomas M. Halloran and Clayton D. Seeber, Earth Science teachers at Poughkeepsie Middle School and Roy Pallett, Science Supervisor, Tasmania, Australia.

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CONTENTS

	Page
FOREWORD	iii
PROGRAM OBJECTIVES AND PERFORMANCE CRITERIA	1
PROCESSES	7
CONCEPTS & UNDERSTANDINGS/QUESTIONS & ACTIVITIES	8
I BROAD-SCALE WEATHER SYSTEMS	8
A Weather	8
B Weather Models and Synoptic Weather Features	8
1 Air Masses	
2 High Pressure Areas	
3 Low Pressure Areas	
4 Fronts	
5 Wave Cyclones	
C Surface Weather Maps	11
II LOCAL WEATHER	12
A Local Weather Information	12
1 Atmospheric Pressure	
2 Air Temperature	
3 Water Vapor	
4 Wind	
5 Clouds	
6 Precipitation	
B Local Weather Changes	13
1 Periodic Weather Changes	
2 Related Weather Changes	
3 Identifying Broad-scale Weather Systems	
4 Correlating Local and Broad-scale Weather	
5 Locally caused Weather	
6 Local Weather and Weather Models	
C Weather Forecasting	15
1 Basis	
2 Degree of Success	
3 Making a Forecast	
III THE ATMOSPHERIC ENVIRONMENT	16
A Composition	16
1 Atmospheric Nitrogen and Oxygen	
2 Carbon Dioxide	
3 Water	
4 Other Atmospheric Constituents	
B Vertical Distribution of Atmospheric Properties	17
1 Air Density	
2 Atmospheric Boundaries	
3 Layers of the Atmosphere	
C Atmospheric Pollution and Contamination	18
1 Air Pollutants	
2 Natural Contaminants	

Page

3 Disposal of Substances
4 Air Pollution Control
5 Other Atmospheric Hazards

IV Energy and Motion in the Atmosphere 19
A Energy and Its Transfer 19
1 Solar Energy
2 Transfer of Energy To and From the Atmosphere
3 Energy in the Atmosphere
B Air Movement 21
1 Unequal Heating
2 Direction of Flow
3 Convection Currents
4 Deflection of Winds
5 Wind Belts
6 Thermal Circulations

V Water in the Atmosphere 23
A Evaporation and Transpiration 23
B Condensation and Sublimation 23
1 Saturation
2 Condensation and Sublimation Nuclei
3 Clouds and Fog
4 Dew and Frost
C Precipitation 24
1 Cause
2 Forms of Precipitation
D The Hydrologic Cycle 25
E Cloud Seeding 25

VI Hazardous Weather 25
A Weather Watches and Warnings 26
B Thunderstorms 26
1 Lightning
2 Flash Floods
3 Winds
4 Thunder
5 Hail
C Tornadoes 27
1 Occurrence
2 Destructive Effects
3 Detection
4 Tornado Safety Rules
D Hurricanes 29
1 Occurrence
2 Destructive Effects
3 Hurricane Safety Rules
E Winter Storms 30
1 Winter Storm Safety
2 Blizzards
3 Ice Storms
4 Snowstorms and Windstorms
F Heat Waves 32

Page

VII Climate 33
A Relationship to Weather 33
B Classifying Climates 33
C Climate Patterns 33
D People and Climate 34
E Microclimates 34

APPENDIX A — LEARNING ACTIVITIES 35

APPENDIX B — CHARTS, TABLES, DIAGRAMS 66

I Weather Map Information 66
Station Model
Air Masses
Front Symbols
Present Weather Symbols

II Pressure — Temperature 67

III Physical Properties of the Atmosphere 68
Dewpoint Temperature Chart
Relative Humidity Formula
Temperature Zones

IV Wave Cyclone Model 69

V Model Data Sheet for Weather Watch 70

VI Wind Chill Table 71

APPENDIX C — SUPPLEMENTAL INFORMATION FOR TEACHERS 72

I Weather and Weather Systems 72

II Weather Models 72

III Satellite Images 74

IV Hazardous Weather 76

PROGRAM OBJECTIVES AND PERFORMANCE CRITERIA

The program objectives and performance criteria below are provided as an aid in ordering the direction and synthesizing the outcomes of the instruction related to this block. The objectives and outcomes (performance) described below for this program are merely illustrative, and, as such, they permit latitude in the selection of additional content. It is implied that student knowledge, understanding, and skills accrued as a result of content selection and instruction will be demonstrable in the manner, and to the minimum extent, described.

Program Objectives	*Performance Criteria*
I. BROAD-SCALE WEATHER SYSTEMS	
The student will be able to describe and explain descriptive weather models which provide frameworks for comprehending the broad-scale workings of the atmostphere and are basic to scientific weather forecasting.	Given appropriate materials, the student will be able to construct and compare descriptive weather models of Highs (anticyclones) and Lows (cyclones).
The student will be able to apply descriptive weather models to relate broad-scale weather systems and local weather conditions.	Given the kind of prevailing weather system (High or Low) and the positions of its center and any existing fronts, the student will be able to describe the probable local weather conditions at various locations within the system.
The student will be able to interpret the symbols appearing on commonly available surface weather maps and relate them to weather models.	Given a surface map, the student will identify Highs, Lows, fronts, and explain other reported weather information. Given a simple surface map, the student will apply descriptive models to describe probable weather conditions at different places represented on the map.
The student will be able to use weather models and maps to make general weather forecasts for specific locations.	Given a series of sequential weather maps, the student will use them and descriptive models to make weather predictions for specific locations.
The student will be able to relate surface and upper-air weather features through the use of three-dimensional weather models.	Given a straight line drawn through a warm or cold front appearing on a surface weather map, the student will construct a cross section of the atmosphere above the line showing probable variations in weather conditions in the vertical.

Program Objectives	*Performance Criteria*
The student will be able to identify major atmospheric features that commonly appear on weather satellite photographs.	Given a set of satellite photographs, the student will locate and identify probable positions of High, Lows, fronts, clouds, and other atmospheric phenomena.

II. LOCAL WEATHER

The student will be able to identify the weather elements commonly observed in weather investigations and explain how they are measured.	Given the task of making direct weather observations, the student will demonstrate the use of suitable instruments, make observations, and accurately record the observations.
The student will relate direct weather observations to the prevailing weather systems and features depicted on current weather maps.	Given the most recent surface weather map, the student will compare direct observational data with map information to point out relationships between local and general weather conditions.
The student will analyze weather information collected during periods of rapid changes in atmospheric conditions and relate them to descriptive weather model features.	Using data collected during the passing of a weather feature (such as a cold front), the student will compare the actual changes in weather elements with those changes which would be expected based on a descriptive weather model.
The student will be able to describe some of the variations of weather elements which occur diurnally and seasonally.	By gathering or being given appropriate weather element data, the student will analyze the data and identify daily or seasonal variations which generally appear.
The student will compare data concerning two or more weather elements in attempts to determine possible relationships among them.	By gathering or being given data on two or more weather elements collected simultaneously, the student will analyze the data and make tentative statements concerning possible relationships among weather elements.
The student will use weather maps, descriptive models, and local data to identify those observed atmospheric conditions which are probably produced locally.	By gathering or being given appropriate weather information, the student will describe probable locally induced atmospheric conditions and their causes.
The student will be able to describe small-scale variations in atmospheric conditions.	Given the task of making direct weather observations, the student will collect and analyze data on specific weather

Program Objectives	*Performance Criteria*
	elements in confined, sheltered, or limited environments and describe the microclimatic variations found.

III. THE ATMOSPHERIC ENVIRONMENT

The student will be able to describe the general physical and chemical characteristics of the atmosphere.	Given physical models, the student will provide evidence of being able to describe the constituents of the atmosphere, their variability, and the extent of the atmosphere.
The student will be able to describe ways in which life is dependent on the atmosphere and ways in which living things affect the atmosphere.	Given an opportunity, the student will list and describe ways in which life (plant, animal, human) has an impact on the atmospheric environment.
The student will be able to describe ways in which the atmosphere is contaminated, name common air pollutants, and explain how air pollution can be reduced.	Given the name of a common atmospheric contaminant (sulfur dioxide, volcanic ash, photochemical "smog," etc.), the student will be able to describe the major cause of the contaminant, some of its impacts on life, substances, and weather; and will make suggestions of ways of reducing the undesirable effects while meeting the needs of society.

IV. ENERGY AND MOTION IN THE ATMOSPHERE

The student will be able to describe qualitative and quantitative aspects of solar energy; the primary source of the energy in the Earth's atmosphere.	Given physical models, the student will describe the nature of sunlight and the astronomical, atmospheric, and geographical factors which produce variations in the amounts of solar energy received at the Earth's surface.
The student will be able to describe in general terms the non-uniform distribution of energy at the Earth's surface and in the atmosphere which is the ultimate cause of weather and climate.	Given physical models, the student will describe the variation in air temperatures with latitude and the differences in the heat storage capacities of land and water.
The student will identify ways in which energy flows to, from, and within the atmosphere.	Given the task to do so, the student will describe how energy can be transferred by radiation, conduction, and convection in and through the atmospheric environment.

Program Objectives	*Performance Criteria*
The student will be able to describe how changes in air temperature bring about differences in air densities and pressures which then lead to atmospheric motions.	Given the apparatus to demonstrate convection, the student will show and explain how the heating of air results in air motion.
The student will describe how moving air appears to be deflected to the right or left as it travels over most of the earth's spinning surface.	Given the proper materials, the student will demonstrate the apparent deflection of an object as it moves over the surface of a rotating object.
The student will be able to describe in general terms the combined effects of differences in air pressure and the earth's rotation in producing the general circulation of the atmosphere.	Given physical models, the student will draw the general circulation of the atmosphere at the Earth's surface and explain the roles of pressure differences and rotation in bringing about the broad-scale wind belts.

V. WATER IN THE ATMOSPHERE

The student will be able to describe the hydrologic cycle.	Given appropriate materials, the student will describe the processes of evaporation, condensation, sublimation, and transpiration and how they are involved in the hydrologic cycle.
The student will be able to describe the concept of water vapor saturation in the air, and how the capacity of the atmosphere to hold water vapor increases as temperature increases.	Given the proper equipment, the student will gather and present evidence that the capacity of a region to hold water vapor varies with temperature and will determine the humidity of a location.
The student will be able to describe the mechanisms of evaporation, condensation, and sublimation.	Given various situations, the student will describe under what conditions evaporation, condensation, and sublimation occurred and what some of the natural products of condensation and sublimation were in the atmosphere and at the Earth's surface.
The student will be able to describe forms of precipitation and the major precipitation mechanisms.	Given the opportunity, the student will describe ice crystals and coalescence-precipitation mechanisms.
The student will be able to describe ways in which weather modification has been attempted.	Given weather situations, the student will describe how "cloud seeding" works and the ways it could be used

Program Objectives	*Performance Criteria*
	to attempt to increase precipitation, suppress hail, and render hurricanes less dangerous.

VI. HAZARDOUS WEATHER

The student will be able to describe the exact meaning of National Weather Service hazardous-weather watches and warnings.	Given the opportunity, the student will write the exact definitions of hazardous-weather watches and warnings.
The student will be able to describe thunderstorms and associated weather hazards of lightning, flash floods, and damaging winds.	Given a simulated severe thunderstorm warning, the student will list those safety rules concerning thunderstorm hazards which can save lives.
The student will be able to describe tornadoes, the general conditions under which they occur and the destruction they can cause.	Given the opportunity, the student will describe tornadoes, the destruction they can cause, and safety rules which should be followed when they occur.
The student will be able to describe the different kinds of winter storms and their associated hazards.	Given a wind chill chart, the student will be able to determine the wind chill index given specific temperatures and wind speeds.
The student will be able to describe hurricanes and their associated storm surges.	Given the opportunity, the student will write a description of hurricanes and storm surges, and will list steps which can be taken to lessen their effects.
The student will be able to describe the general effects of heat waves on humans.	Given a heat wave situation, the student will be able to describe the physiological effects of the prolonged high temperatures and/or humidity on a human.

VII. CLIMATE

The student will be able to identify climate and the factors which are used to classify climate.	Without the aid of reference material, the student will be able to define climate and identify those factors commonly used to describe climate.
The student will be able to identify those geographical features which act to modify climate.	Given the task to do so, the student will describe those geographical features which act to modify local climate.

Program Objectives	*Performance Criteria*
The student will be able to describe ways in which climate and people interact.	Given various climate conditions, the student will describe the ways climate impacts life in the community, and the ways people affect climate.
The student will be able to describe what is meant by microclimates and why they are important to life.	Given suitable equipment, the student will investigate a microclimate, analyze the findings, and indicate the possible impacts on life.

PROCESSES

One of the major objectives in all science courses is the development of competence in processes used in science. The learning activities beginning on p. 35 in this publication will assist students in attaining this objective. Each activity is keyed to one or more of the processes listed below. For example, activity (E-1) involves processes [1], [2], [3], and [12]. In general, the processes are listed in order of predominance within the activity and appear to the right of the activity's title.

[1] Observing objects and phenomena

[2] Describing observations

[3] Selecting suitable measuring instruments

[4] Developing skills in using laboratory equipment

[5] Measuring objects and phenomena

[6] Performing laboratory techniques

[7] Estimating measurements within limits of accuracy

[8] Recognizing a problem

[9] Formulating a working hypothesis

[10] Designing appropriate tests of a hypothesis

[11] Designing suitable procedures for experimental tests

[12] Processing experimental data

[13] Organizing data to show a functional relationship

[14] Interpreting observations and data

[15] Interpolating and extrapolating

[16] Evaluating a hypothesis in the light of data obtained

[17] Formulating generalizations based on relationships

[18] Recognizing the need for a theoretical model

[19] Formulating a theoretical model to accommodate knowledge

[20] Designing relationships satisfied by a model

[21] Deducing a hypothesis from a theoretical model

[22] Interpreting and evaluating tests of a model

[23] Producing a revised, refined, or extended model

CONCEPTS & UNDERSTANDINGS/QUESTIONS & ACTIVITIES

I. BROAD-SCALE WEATHER SYSTEMS

Weather is generally dominated by broad-scale weather systems which are symbolically depicted on surface weather maps and which can be described by models.

How can broad-scale weather information be acquired? (E-1)

A Weather

Weather deals with the short-term variations of the atmosphere.

What is weather? (See Appendix C, page 72, I for background information for this section.)

Weather arises from the unequal distribution of energy in the Earth's envelope of air.

What are the causes of weather?

Uneven heating of the atmosphere brings about pressure differences which put air into motion.[1]

Away from the Equator, the motion of air is altered by the Earth's rotation. Often, gigantic whirls called High and Lows result.

What are the major broad-scale weather systems of the middle latitudes?

Highs and Lows play major roles in producing weather in the middle latitudes by carrying certain general characteristics with them as they form and migrate across the Earth's surface. They modify as they move and interact.

B Weather models and synoptic weather features[2]

Descriptive models of synoptic weather systems and features provide frameworks for comprehending vast amounts of weather information.

What are descriptive weather models? What are examples? (See Appendix C, page 72 II for background information for this section.)

---

[1]Air pressure is determined by the weight of the overlying air. It is the force that the air above exerts on every unit of area. Heating causes air to expand and cooling causes it to contract. Temperature differences produce density differences which in turn produce pressure differences. Pressure differences bring about unbalanced forces which cause air to move.

[2]The term synoptic refers to an overall view based on information collected simultaneously over a wide area.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
1 air masses	
Air masses form when air residing over a large, nearly uniform surface takes on the temperature and moisture characteristics of that surface.	*What happens to air that remains over the same surface for several days or more?* (E-2) *(See Appendix C, page 72 II for background information.)*
Air masses are more likely to form in a particular source region at one time of the year than at another.	*How do air masses affect our weather?*
Air masses transport sets of weather conditions which change as they move over new surfaces.	*What happens to air masses as they migrate?* (E-3)
Air masses can be identified and classified by type according to their source regions, their moisture characteristics, and their temperatures relative to those of the surfaces over which they are moving.	*How are air masses classified?* (E-2)
After migrating from their source regions in higher or lower latitudes, air masses tend to move in an easterly direction over the contiguous United States.[3]	*What are the paths air masses frequently follow?* (E-3)
2 high pressure areas	
High pressure areas (Highs) are regions of relatively high atmospheric pressure represented on a surface weather map by closed isobars.[4]	*How are Highs identified?* (E-4)
As surface air pressures are generally highest in the centers of air masses, Highs often denote the presence of air masses.	
Within a High, winds blow clockwise (anticyclonic circulation) and spiral outward from the center.[5]	*What is the surface circulation pattern in a High?* (E-5)

---

[3]Different air masses tend to dominate the weather over various sections of the country at different times of the year. For example, continental polar air masses tend to dominate weather in the Northeastern United States in winter whereas maritime tropical air masses frequently exert a major influence in the summer.

[4]Air masses and Highs are not identical terms.

[5]Statements concerning atmospheric circulation apply to the Northern Hemisphere unless otherwise noted.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
The air in Highs tends to descend and is warmed by compression, resulting in generally fair and clear weather.[6]	*What happens to the temperature and relative humidity of air as it sinks in a High?* (E-6)
3 low pressure areas	
Low pressure areas (Lows) are regions of relatively low atmospheric pressure represented on a surface weather map by closed isobars.	*How can Lows be identified?* (E-4)
Within a Low, winds blow counterclockwise (cyclonic circulation) and spiral inward toward the center.	*What is the surface circulation pattern in a Low?* (E-5)
Air in a Low tends to rise and is cooled by expansion, producing generally cloudy and sometimes stormy weather.	*What happens to the temperature and relative humidity of rising air in a Low?* (E-7)
4 fronts	
Air masses come into direct contact with one another in the continuous atmosphere, but the air in them does not readily mix because of density differences.[7]	
The boundaries separating air masses tend to remain distinct. These are called fronts.	*What is a front?* (E-8)
Abrupt changes in weather elements can occur across fronts.	*What differences in weather conditions can be observed across a front?* (E-9)
The kind of front depends upon motion of the boundary or boundaries between different air masses.[8]	*What are the different kinds of fronts? How are they named?* (E-10)

---

[6] The descending air in Highs accounts for many of the desert regions of the world.

[7] Air density is determined by its temperature and water vapor content. The colder and/or drier the air, the denser it is. The warmer and/or more moist it is, the lighter the air.

[8] Moving air mass boundaries, which cause cold air to replace warm air at the Earth's surface, are called cold fronts. When warm air is replacing retreating cold air, the boundary is a warm front. A front with little or no movement is called a stationary front. An occluded front is one in which a cold front has overtaken a warm front.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
In general, particular weather characteristics are associated with particular kinds of fronts. Moving fronts carry these characteristics with them as they sweep across the Earth's surface.[9]	
5 wave cyclones	
In the middle and high latitudes, wave cyclones frequently form and move along the boundaries separating warm and cold air masses.	*Where in the atmosphere are wave cyclones likely to be found? (See Appendix C, page 72 II for background information on this section.) (See Appendix B, page 69 IV.)*
Wave cyclones typically exhibit common structure including a center of low surface pressure, warm and cold air sectors, fronts, cloud and precipitation areas, and cyclonic circulation.	*What variations in weather are typically found in different parts of wave cyclones?*
Wave cyclones may be viewed as having a life history in which the system forms, intensifies, and eventually dissipates.	*What happens to these storm centers over a period of several days?*
Wave cyclones may or may not change latitude as they move in generally eastward directions over the contiguous United States.	*What paths do these storm centers seem to follow?*
C Surface weather maps	
Surface weather maps symbolically depict weather conditions at many locations and display broad-scale weather systems and features. Simplified maps often include only the latter.[10]	*What are examples of symbols found on surface weather maps? What do they mean? (See Appendix B, page 66 I.)* (E-11)
Weather maps evolve from observations taken simultaneously at many locations.	

[9] Stratiform clouds are typically found in advance of warm fronts as are extensive areas of steady precipitation. Cumuliform clouds are more typically found in a relatively narrow band along cold fronts where showers and thunderstorms are common.

[10] Care should be taken to determine whether or not available maps are actually surface maps or forecast maps. Forecast maps appearing in newspapers should not be used as surface maps.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Generalizations concerning the sizes of broad-scale weather systems and features, their motions, and their life histories can be determined through weather map studies.	*How large are air masses, wave cyclones, and fronts?* (E-12)
Current weather maps provide information about broad-scale systems and features which typically dominate local weather.	
The combined use of surface weather maps and satellite photographs can lead to increased understandings of the workings of the atmosphere.	*What information can satellite photos provide?* (E-13) *(See Appendix C, page 74, III for background information.)*
II. LOCAL WEATHER	
Local atmospheric conditions are determined by prevailing broad-scale weather systems which are modified by daily and seasonal factors, topographical features, and by human activity.	*What factors cause the weather we experience locally?*
A Local weather information	
The study of weather requires the collection of data for selected weather elements.	*What kinds of weather information are usually collected?* (E-14)
1 atmospheric pressure	
Air pressure is determined by the weight of the overlying air.[11]	*What is air pressure?* (E-15) *(See Appendix B, page 67 II.)*
Air pressure and its tendency (rising, steady, falling) are important indicators of passing broad-scale weather systems.	*What can barometric tendency help to tell us?*
2 air temperature	
Air temperatures vary considerably over time and reflect the heat energy content of the air.	*Why must thermometers be shielded from rain and direct sunlight?* (E-16) *(See Appendix B, page 67 II.)*

[11] Air pressure has been traditionally measured by balancing the weight of a column of air extending from the surface of the Earth to the top of the atmosphere against the weight of a column of mercury with the same cross-sectional area. The height of the mercury column (in inches or centimeters) is frequently quoted as the "pressure" of the atmosphere. Weather maps record the atmospheric pressure in millibars.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Thermometers must be properly ventilated while protected from radiation and precipitation to measure air temperatures.	
3 water vapor	
The water vapor content of the air and its variations are basic to many atmospheric processes.	*What is relative humidity?* (E-17)
Both absolute and relative water vapor measurements are important in weather study.[12]	*What is dew point?* (E-17) *(See Appendix B, page 68* III.*)*
4 wind	
Wind is measured in terms of its speed and the direction from which it is blowing.	*How is wind measured?* (E-18)
5 clouds	
Clouds are described in terms of their vertical (cumuliform) or horizontal (stratiform) development, heights of occurrence above ground level, and the amount of cloud cover (cloudy, partly cloudy, clear).	*What can clouds tell us about atmospheric conditions?* (E-19)
6 precipitation	
Precipitation includes all kinds of liquid or solid water particles which fall from the atmosphere and reach the ground.	*What are the different kinds of precipitation?* (E-20)
B Local weather changes	
Weather elements can vary with the time of day and season, elevation, nature of the underlying surface, and the influence of prevailing weather systems and features.	

[12]Water vapor in air is usually measured for weather purposes as dew point and relative humidity. They are both related to the fact that the capacity of air to hold water vapor decreases as the temperature decreases. Dew point is the temperature to which the air has to be cooled such that the amount of water vapor in the air is the same as the capacity of the region to hold water vapor. Relative humidity is the ratio (as percent) of the amount of water vapor in the air to the maximum amount the region could hold at a given temperature.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
1 periodic weather changes	
Some weather elements vary more or less periodically with time of day or season.	*What weather elements appear to change periodically?* (E-16) *(See Appendix B, page 68 V.)*
2 related weather changes	
As is the case in all physical systems, changes within the atmospheric system are somehow interrelated. It is sometimes possible to detect relationships among changes in two or more weather elements.	*Can relationships be found among two or more weather elements? Temperature and pressure? Pressure and cloudiness? Others?* (E-21)
3 identifying broad-scale weather systems	
Local weather element measurements and their changes can often be used to identify broad-scale weather systems and to track their movements.	*Can Highs, Lows, and fronts be detected with local weather data?* (E-22) (E-23)
4 correlating local and broad-scale weather	
Local weather observations can often be used to correlate local weather with broad-scale weather systems and features appearing on concurrent weather maps.	*Do local weather data and concurrent weather map features fit together?* (E-22) (E-23)
5 locally caused weather	
Comparisons of local weather data with information on concurrent broad-scale weather systems can lead to the identification of weather conditions caused or modified by local environmental factors.[13]	*Can weather conditions of local origin be detected at times? What are they?* (E-24)
6 local weather and weather models	
Local weather observations can be used to verify and, if necessary, modify descriptive weather models.	*Do local weather observations fit descriptive weather models? (See Appendix C, page 76, IV, for background information.)*

[13] In New York State the Atlantic Ocean, lakes, mountains, and cities exert observable effects on local weather at different times.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
C Weather forecasting	
1 basis	
Successful forecasting of weather depends upon the knowledge and application of empirical and theoretical relationships to past and present weather conditions.[14]	*Is weather forecasting an art or a science?*
2 degree of success	
The goal of forecasting is to make an accurate prediction of future weather. Such a goal is an ideal which may never be attained although success in forecasting has improved with the use of numerical weather models, computers, and weather satellites.[15]	*Why is weather forecasting difficult?*
Because of their complexity, weather predictions are often stated as probabilities.	
3 making a forecast	
Short-term (less than a day) general forecasts can be attempted by noting current local conditions, examining the most recent weather maps, and applying knowledge concerning weather models.[16]	*How can a general, short-term weather forecast be made?* (E-25)
There is a tendency for weather conditions to remain nearly the same from day to day. This persistence should be considered, especially in the absence of adequate weather information.[17]	*How does today's weather compare with yesterday's?* (E-14)

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[14] A distinction should be made between observing the weather and forecasting the weather. Observing calls for objective methods for describing actual atmospheric conditions while forecasting is a prediction of future conditions based partially on the judgment of the forecaster.

[15] A major reason for the difficulty in making forecasts is the number of variables involved. Each weather element is in some way related to every other element. If one element changes, it affects every other one in some way. Most National Weather Service forecasts are made for relatively large areas and the local weather in a given community could differ appreciably from the general weather of the area.

The use of probabilities provides perspective to forecasts.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Modern, scientific forecasting requires advanced training, surface and upper-air weather data, and the use of highly sophisticated techniques and equipment. Numerical atmospheric models put in equation form and solved on computers provide guidance which is interpreted by the professional weather forecasters.	*What is needed to make scientific forecasts?*
The National Weather Service is the governmental agency which has the responsibility to make weather forecasts for the general public.	

III. THE ATMOSPHERIC ENVIRONMENT

A Composition

The atmosphere is composed of a mixture of gases containing minute quantities of solid and liquid particles.	*What gases are found in the atmosphere?* (E-26)
1 atmospheric nitrogen and oxygen	
The atmosphere is largely composed of nitrogen (about 78% by volume) and oxygen (about 21%), gases whose concentrations are relatively stable.[18]	
Atmospheric oxygen, needed by almost all organisms to survive, is constantly replenished by plants via photosynthesis.	*Where does atmospheric oxygen come from?* (E-27)
2 carbon dioxide	
Carbon dioxide (CO_2), although found in small amounts in the atmosphere compared with nitrogen and oxygen, appears to have a significant effect on atmospheric temperatures.[19]	

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[16] Individual weather element tendencies, such as pressure and temperature changes, are often useful in predicting weather in the very near future. Using the tendencies of several elements together is even more reliable for predicting weather several hours or even a day ahead.

[17] Abrupt changes in the weather are the exception rather than the rule. Weather tends to change gradually as general weather systems are large, frequently slow-moving, and slow in changing.

[18] Nitrogen dilutes the oxygen which readily reacts chemically with other substances. Care must be exercised in areas where oxygen tanks are stored or pure oxygen is being used. Rusting can be retarded by painting or oiling iron or steel.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
The amount of carbon dioxide in the atmosphere appears to be increasing, causing atmospheric temperatures to be higher than they might otherwise be.	
3 water	
The substance water can be found in the atmosphere in solid, liquid, and vapor phases. It is frequently changing phase.	*What gaseous component of the atmosphere is routinely measured by meteorologists?* (E-28)
Water vapor can be found in concentrations from near 0% to 4% locally in the atmosphere.	
4 other atmospheric constituents	
Many other substances can be found in the atmosphere, some occurring naturally and some as the result of human activity. Many of these can have effects on the state of the atmosphere and on life.[20]	*What are examples of substances found in minute quantities in the atmosphere?* (E-29)
B Vertical distribution of atmospheric properties	
The various properties of the atmosphere change with altitude.	*(See Appendix B, page 68* III.*)*
1 air density	
The atmosphere is held to earth by gravitational forces. The densest part of the atmosphere lies at sea level and becomes less dense at increasing altitude.	*What determines air pressure anywhere in the atmosphere?* (E-15)

---

[19]Carbon dioxide absorbs heat radiation from the Earth in the "greenhouse effect," warming the atmosphere to temperatures higher than would be expected if the CO_2 were absent.

[20]Ozone is a minor but extremely important constituent. For example, its formation and dissociation (maximum concentration at about 20 kilometers altitude) brings about a reduction in the amount of ultraviolet radiation reaching the Earth's surface. Incidence of skin cancer is associated with exposure to ultraviolet radiation. Carbon monoxide is a colorless, tasteless, and highly poisonous gas produced by the incomplete combustion of fuels containing carbon. Proper ventilation is necessary when burning carbon fuels to avoid carbon monoxide poisoning.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
2 atmospheric boundaries	
There is no clear-cut upper boundary to the atmosphere. The lower boundary, while more distinct, is not always clearly defined.[21]	*How thick is the atmosphere?* (E-30)
3 layers of the atmosphere	
Based on different criteria such as changes in composition and temperature, and radiation effects, the atmosphere can be thought of as being made up of layers or shells.[22]	*What are some of the criteria which can be used to divide the atmosphere into layers or shells?* (E-31)
C Atmospheric pollution and contamination	
Substances found in the atmosphere as the result of human activity and natural events can have adverse effects on humans, animals, vegetation, or materials. Undesirable substances in the atmosphere, regardless of origin, are called contaminants. Air pollutants are the products of human activity.	
1 air pollutants	
Air pollutants include undesirable gases, liquids, and solid particles such as carbon monoxide, sulfur dioxide, incompletely burned rubbish, and photochemical "smog." Also included are radioactive materials and heat.[23]	*What determines whether or not a substance is an air pollutant?* (E-32) (E-33)

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[21] The air in the upper atmosphere gradually thins to the density of "space." The outer boundary of the atmosphere is sometimes arbitrarily defined for convenience. For example, how high would you have to go to become a space traveler?

[22] Based on temperature change with height, the lowest layer is called the troposphere and above it is located the stratosphere. Another layer commonly referred to is the ionosphere. This is the upper portion of the atmosphere containing significant numbers of electrically charged particles.

[23] Acid rain (and acid fog) is simply a dilute acid (usually sulfuric acid) caused by the dissolving of gaseous pollutants such as sulfur dioxide in precipitation. It has been suggested by some scientists that the sulfur dioxide is produced by the burning of coal and oil. Acid rain appears to have a detrimental effect on plant and animal life.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
2 natural contaminants	
Nature can contaminate the atmosphere. Examples include pollen, dust, volcanic ash, and the combustion products of forest fires.[24]	*Does nature contaminate the atmosphere?* (E-24)
3 disposal of substances	
The atmosphere plays a major role in dispersing toxic and harmful substances resulting from human activity and natural events.	*What major role does the atmosphere play in disposing of waste materials?*
4 air pollution control	
Practically every activity releases some contaminants into the atmosphere. Consequently, air pollution will never be eliminated. The purpose of air pollution control is to reduce air pollution to acceptable levels.	
Governmental agencies, industry, and people are responsible for determining acceptable air quality standards and in taking steps to assure their compliance.	*Who is responsible for air quality?*
5 other atmospheric hazards	
Noise and different kinds of electromagnetic radiation are among other atmospheric hazards which can have impact on the quality of life.	

IV. ENERGY AND MOTION IN THE ATMOSPHERE

A Energy and its transfer

Weather arises from the unequal distribution of energy in the Earth's ocean of air and the surface below.

1 solar energy

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[24] Suspended volcanic ash in the atmosphere after major volcanic eruptions has reduced the amount of sunlight reaching the Earth's surface sufficiently to lower air temperatures dramatically and change climates.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
a source of atmospheric energy	
The Sun is the primary source of the energy of the atmosphere.[25]	*What are some effects of the Sun's energy?* (E-35)
b transfer of solar energy	
The Sun's energy, which is received by the Earth and its atmosphere, arrives in the form of radiation.[26]	*What is the nature of the Sun's energy?* (E-36)
2 transfer of energy to and from the atmosphere	
a gain of energy	
The atmosphere is partially heated by direct solar radiation.	*How does the rate at which radiation is absorbed vary?* (E-37)
The lower atmosphere receives most of its energy from solar energy which is absorbed by the Earth's surface and then transferred to the atmosphere by radiation, evaporation (latent heat), convection, and conduction.[27]	*How does the atmosphere receive its energy?* (E-37) (E-38)
b loss of energy	
The atmosphere loses energy to space by heat (infrared) radiation.	*How does the atmosphere lose heat energy?* (E-39)
c energy balance	
The Earth and its atmosphere radiate to space an amount of energy equal to that absorbed from the Sun.[28]	*Why does the atmosphere reach radiative balance?* (E-40)

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[25] The energy radiated by the Sun is thought to result from thermonuclear reactions in which some of the Sun's mass is converted into energy.

[26] The Earth receives solar radiation from throughout the electromagnetic spectrum. While most is visible and infrared radiation, the Sun also emits significant quantities of ultraviolet and x-radiation.

[27] The energy within the atmosphere is transferred from place to place primarily by convection.

[28] On a global scale, this balance results in the earth neither heating up nor cooling down; that is, worldwide temperatures remain constant. However, there is evidence that, over long periods, global temperatures do vary enough to significantly change climate.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
3 energy in the atmosphere	
The distribution of energy in the atmosphere is not uniform.	
B Air movement	
Atmospheric circulation is brought on by the unequal distribution of energy.	
1 unequal heating	
The unequal distribution of energy in the lower atmosphere is primarily caused by the angle at which the Sun's rays strike the Earth and its atmosphere, and by the nature of the Earth's surface.[29]	*What causes differences in heating rates in the atmosphere?* (E-41) (E-42)
The uneven distribution of energy produces variations in air temperature which result in variations of air density and pressure.	*What is the relationship between air temperature and pressure?* (E-43)
2 direction of flow	
Variations in air pressure cause air to tend to move from regions of high pressure to regions of low pressure.	*What is the direction of air flow in the atmosphere?* (E-43)
3 convection currents	
Cold air is more dense (heavier) than warm air. As a result, cold air sinks while warm air rises.	*How are convection currents formed?* (E-44)
Convection currents develop where cold air sinks, moves to a region of lower pressure (high temperature) and then rises.	
4 deflection of winds	
The rotation of the Earth causes moving air in the Northern Hemisphere to appear to be deflected to the right.[30]	*How does the Earth's rotation affect the Earth's wind pattern?* (E-45)

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[29]The Sun's path is high in the sky throughout the year at low latitudes while at higher latitudes it is lower. The greater the altitude of the Sun, the more concentrated are its rays that strike the Earth's surface.

Snow reflects more sunlight and absorbs less than a vegetated surface.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
Forces arising from differences in air pressure and the Earth's rotation cause winds in the Northern Hemisphere to rotate clockwise (anticyclonic circulation), as viewed from above, around centers of high pressure and counterclockwise (cyclonic circulation) around centers of low pressure.	
5 wind belts	
The planetary temperature distribution and the effect of the Earth's rotation result in worldwide pressure zones and large-scale wind belts. The wind belts result in a general (or averaged) pattern of air movement in the United States from west to east. However, from day-to-day and season-to-season there is a great deal of north-south flow as well.[31]	*What is the Earth's wind belt pattern?* (E-46)
6 thermal circulations	
a land and sea breezes	
Large temperature differences across coastlines can produce sea breezes by day and land breezes by night.	*What causes sea breezes?* (E-47)
b monsoons	
Monsoons are related to ocean currents, the jetstream, and high summer temperatures on land. These high summer temperatures cause convection cells carrying moist air to move further than normal from the sea. Warm air in these cells rises, is cooled, and precipitation results. In winter, a reverse effect results.	*What causes monsoons?* (E-47)

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[30]This deflection is known as the Coriolis force and is the result of the tendency of the air to move in a straight line while traveling over the surface of the rotating Earth. Observation of the air motion from the surface of the Earth makes it appear to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. Observation of the same motion from space shows the air to be tending to move in a straight line.

[31]If the Earth did not rotate (while assuming other conditions remained the same), a permanent surface low pressure belt probably would develop at the equatorial region with two

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES

V. WATER IN THE ATMOSPHERE

Water in liquid, vapor, and solid phases is continually flowing to, from, and within the atmosphere. Its presence and flow are of great significance to weather and climate.

A Evaporation and transpiration

Water is supplied to the atmosphere by evaporation. Over land, transpiration (resulting in evaporation from plant leaves) often plays a major role in this process.

What is transpiration? What does the term evapotranspiration mean? (E-48)

B Condensation and sublimation

1 saturation

At any given temperature, there is a limit to the amount of water vapor the air can hold. The higher the temperature, the more water vapor the air can hold. When the air is filled to capacity, it is saturated and the relative humidity is 100%.

What are condensation and sublimation? (E-49)

What is meant by saturation?

Air can become saturated by the introduction of more water vapor, through heat loss by radiation, through contact of air with cold surfaces, by the mixing of warm and cold air, and through cooling by expansion.[32]

How does air become saturated? (E-50)

2 condensation and sublimination nuclei

Water particles form in the air by the condensation or sublimination of water vapor onto tiny particles of matter called nuclei.[33]

What is the role of condensation nuclei? (E-51)

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high pressure areas at the poles. Surface winds would always be flowing towards the Equator, while winds aloft would flow towards the poles. If the earth were to begin rotating, the Coriolis force would cause the large size circulation cells to break up into smaller cells. After achieving a rotational period of 24 hours, the Earth's general circulation would probably become the same as it is now.

"Rivers" of high speed air about seven miles up separate cold polar air from warm tropical air. These are called jet streams.

[32] In buildings the humidity of the air can be controlled by adding moisture

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
While various kinds of particles can act as nuclei, some particles are more efficient than others in bringing about condensation or sublimination.[34]	*What are some examples of efficient condensation and sublimation nuclei?*
3 clouds and fog	
Clouds and fog are composed of minute water particles suspended in the air.[35]	*How do clouds and fog form?* (E-52)
Clouds and fog will form only when the air is saturated and sufficient condensation nuclei are present.	
Cumulus clouds have vertical development and may exhibit considerable turbulence.	
Stratus (layer-like) clouds have little vertical development and contain relatively little turbulence.	
4 dew and frost	
Dew is formed by the condensation of water vapor from the air directly onto objects.	*How do frost and dew form?* (E-53)
Frost is formed by the sublimation of water vapor directly onto objects.	
C Precipitation	
1 cause	
Cloud particles must be greatly enlarged if precipitation is to occur.[36]	*How can raindrops be measured?* (E-54)
Ice crystal growth can result in cloud particles heavy enough to fall through the cloud, and sometimes from the cloud to Earth.	

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to the air (drying clothes, humidifiers) or by removing it (dehumidifiers). Humidity affects human comfort and health so there are benefits in its regulation.

[33] It has been found in the laboratory that relative humidities of 400% or higher can be attained in air samples carefully cleaned of particles which are capable of acting as condensation or sublimination nuclei.

[34] It appears that condensation nuclei are usually tiny salt crystals, drops of sulfuric acid, or smoke particles. The concentration found in the atmosphere varies enormously. Continental and urban air tends to contain high concentrations while maritime and rural air contains relatively few. Sublimination nuclei are usually microscopic particles of soil or sand.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
2 forms of precipitation	
The type of precipitation, such as rain or snow, depends largely on the temperature of the air at the place of origin and through which it falls.[37]	
D The hydrologic cycle	
The transfer of water in the liquid, gaseous, and solid states is constantly occurring between the atmosphere and the Earth, and within the atmosphere.	*How is water transferred on the Earth?* (E-55)
E Cloud seeding	
Precipitation can be induced by producing the same physical conditions necessary for naturally occurring precipitation.[38]	*What are the conditions which must exist if precipitation is to take place?*
Various substances, when dispersed in the air under certain cloud conditions, appear to cause precipitation by promoting cloud particle growth.[39]	*What substances have been used in cloud seeding attempts?*
Cloud seeding has been attempted to lessen the effects of hazardous weather. Examples include experiments to modify hailstorms and hurricanes.	
VI. HAZARDOUS WEATHER	
Weather, on certain occasions, can threaten life and property. Steps can be taken to lessen the effects of hazardous weather.[40]	*(See Appendix C, page 76 , IV for background information for this section.)*

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[35]Fogs are clouds in contact with the Earth's surface.

[36]On the average, the mass of one raindrop is about a million times greater than the mass of one cloud particle.

[37]Research has shown that precipitation at our latitudes seems to be initiated by the growth of ice crystals in clouds containing a mixture of ice crystals and supercooled water droplets. If temperatures are low enough, the result is snow at the Earth's surface. If temperatures in the lower part of the cloud are above freezing, the ice crystals melt to form droplets which continue to grow by coalescence as they fall through the cloud. The result is rain at the Earth's surface.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
A Weather watches and warnings	
The National Weather Service has developed warning systems to inform the public of weather hazards.[41]	*What are the exact definitions of National Weather Service watches and warnings?*
Watches indicate that the hazardous weather conditions described may occur.	*What action is appropriate for a watch and a warning?*
Warnings indicate that the hazardous conditions are either imminent or occurring.	
B Thunderstorms	
Thunderstorms may occur along fronts, near mountain barriers, and within air masses when warm, humid air is forced upward. Their frequency and potential for violence make them one of nature's great destroyers.	*Where, when, and how do thunderstorms, lightning, and flash floods occur?*
1 lightning	
Lightning, always accompanying thunderstorms, is a huge electrical discharge.[42]	*What is lightning and how is it caused?* (E-56)
Lightning is a major killer. Some safety rules to follow when lightning threatens are:	*What are those actions which should and should not be taken during thunderstorms to guard against lightning?*
(a) Stay indoors and away from open doors and windows, stoves, metal pipes, sinks, plug-in electrical appliances, and telephones. (b) Get inside an enclosed all-metal vehicle. (c) Get out of the water, off beaches, and off small boats.	

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[38] Most cloud seeding experiments have been carried out on clouds composed of supercooled droplets with a deficiency of ice crystals. The introduction of substances into these clouds to increase the number of ice crystals appears to have resulted in precipitation in many cases. The success of these experiments in increasing precipitation has been questioned as it is difficult to prove that "natural" precipitation would not have occurred anyway.

[39] Dry ice and silver iodide are examples of cloud seeding materials. Dry ice is so cold that it freezes cloud droplets as it drops through the cloud. The frozen particles then grow at the expense of the remaining supercooled droplets in the region. Silver iodide crystals, apparently because of characteristics similar to those of ice crystals, act as nuclei on which water vapor sublimes. Consequently, these newly formed ice crystals with silver iodide nuclei enlarge while the supercooled droplets surrounding them evaporate.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
2 flash floods	
Heavy thunderstorm precipitation can bring on sudden flooding. Moving at incredible speeds, flash floods can cause water levels to rise 5 meters or more in minutes.	*Can thunderstorms produce flooding? Can it be dangerous?*
Flash flood safety rules include: (a) Act quickly and seek higher ground. (b) Get out of areas subject to flooding. (c) Avoid areas already flooded. (d) Do not attempt to cross a flowing stream on foot or by car.	
3 winds	
Strong gusts (shear winds) occur directly beneath mature thunderstorm cells. These straight-line winds can cause damage.[43]	*Can any thunderstorm produce damaging winds?*
4 thunder	
The rapid expansion of air due to intense heating during the lightning discharge produces thunder.[44]	*How is thunder caused?* (E-57)
5 hail	
Hail can occur during severe thunderstorm activity. It almost always accompanies tornadoes.[45]	*What is hail and how is it formed?*
C Tornadoes	
Tornadoes are violently rotating local winds associated with severe thunderstorms. They strike suddenly, do not last long, and can cause great destruction and death.	*When, where, and how do tornadoes form?*

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[40] Adequate hazardous weather preparedness and response can reduce losses. Familiarity with these hazards, their causes, and their destructive potential can lead to proper actions which will prevent or lower losses.

[41] The National Weather Service's NOAA Weather Radio has been designated as the official warning system for natural hazards and nuclear attack.

[42] Lightning is the electrical "spark" which occurs between differently charged portions of clouds or between clouds and the Earth's surface. It is brought about by the development of large voltage differences as a result of electrical charge separation in thunderstorms. How the charge separation occurs is not well understood. Recognition of lightning as being an electrical phenomenon is basic when one considers the protection of life and property from lightning.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
1 occurrence	
Tornadoes are short-lived, severe local storms often observable as funnel-shaped appendages to a thunderstorm cloud.	*What are the general characteristics of tornadoes?* (E-58)
They have occurred in every state, at all times of the year, but most often in spring in the warm part of the day between noon and midnight.[46]	*Does New York State have tornadoes?*
2 destructive effects	
Tornadoes do their destructive work primarily through the combined action of their strong winds and the impact of wind-borne missiles.[47]	
3 detection	
As the general conditions favorable for tornado formation are known, it is possible to forecast their probable occurrence. Listen for National Weather Service watches and warnings.	*Under what general conditions do tornadoes occur?*
Maintain your own tornado watch during periods of severe thunderstorm activity. Your first awareness of a tornado might be by sighting the funnel cloud or hearing its "freight-train" roar.	
4 tornado safety rules	
(a) Your immediate action can save your life. (b) Stay away from windows, doors, and outside walls. Protect your head. (c) Go the the cellar (basement) or to an interior part of the lowest building level - closets, bathrooms, or	*What steps should be taken if a tornado is sighted or a tornado warning is issued?*

[43]Those strong gusts are special threats to aircraft. In recent years a number of planes have been caught in them while in their landing approaches. Crashes have resulted with many lives lost.

[44]The distance to the lightning channel can be estimated by measuring the time between the lightning flash and the thunder. Light reaches the observer almost instantaneously while the sound travels about 1,100 feet per second (340 meters per second). Multiply the intervening time by the speed of sound (1/5 mi/sec or 1/3 km/sec) to determine the distance.

[45]Hail occurs only in the presence of thunderstorms. It is thought hailstone growth is primarily due to the

interior halls. Get under something sturdy.

(d) In large buildings go to pre-designated shelter areas or in interior hallways on the lowest floors.

(e) If in mobile homes or vehicles, leave them and go to a substantial shelter. If none is available, lie flat in the nearest ditch or culvert with your hands shielding your head.

Why are mobile homes so vulnerable to tornado and wind damage?

D Hurricanes

Hurricanes are gigantic whirling storms with high winds, torrential rains, and related storm surges capable of causing widespread flooding and destruction.

When, where, and how do hurricanes occur? (E-59)

1 occurrence

Hurricanes tend to form over oceanic surfaces during the warmest part of the year. August through October is when Atlantic hurricanes are most likely to form.[48]

It is in the towering wall clouds surrounding the relatively calm eye where winds and precipitation are greatest.

What is the structure of a typical hurricane?

As hurricanes approach and cross shorelines, they bring ashore mounds of water topped by wind-blown waves. These storm surges are often 50 miles wide near the area where the eye makes landfall. Storm surges can be 10, 15, or more feet above normal sea level.[49]

What is the storm surge and why is it so dangerous?

2 destructive effects

Most hurricane-related deaths are due to storm surge flooding, although the high winds and heavy rainfall (fresh water flooding) take their toll.

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coalescence of supercooled droplets with ice particles in regions of strong updrafts. The layering often seen in hard hail appears to be a function of the rate at which coalescence and freezing occur.

[46] On the average, three confirmed tornadoes have been reported in New York State each year.

[47] Sudden pressure changes appear to have little effect due to the venting of buildings by ripping winds and flying debris.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
3 hurricane safety rules	
(a) Hurricane watches are issued for coastal areas when there is a threat of hurricane conditions within 24 to 36 hours. Hurricane warnings are issued when hurricane conditions are expected in 24 hours or less. Actions to protect life and property should begin immediately when a warning is issued.	*What are the exact definitions of hurricane watches and warnings?*
(b) Persons living in low-lying coastal areas which could be subjected to the storm surge should evacuate threatened areas. Anyone living in flood-prone areas should seek refuge at higher elevations.[50]	*What actions should individuals and families take if a hurricane threatens?*
(c) Property should be prepared for the effects of high winds and flying debris. Board, shutter, or tape windows.	
(d) Non-perishable food, water, medicines, flashlights, and the like should be acquired and safely stored for emergency use.	
(e) Stay indoors during the hurricane.[51]	
E Winter storms	
Snow, low temperatures, wind, and freezing rain or drizzle are components of winter storms. Singly or in combination, they can be hazardous.	
1 winter storm safety	
(a) Prepare for winter storms by laying in supplies of food, heating fuel, batteries, medicines, and other necessities.	*What actions should be taken to prepare for winter storms in general?*

[48]The primary source of energy in a hurricane is the latent heat released during condensation. Consequently, hurricanes tend to intensify over warm water surfaces where energy is constantly being supplied to the system by evaporation of sea water at the surface and condensation in the air. Hurricanes tend to dissipate over land or cold water surfaces as less water vapor is fed into the system.

[49]Hurricanes typically lose their characteristic structure soon after landfall. At times they become persistent Lows from which great quantities of rain fall. Flooding from these can be disastrous, as was the case with the remains of Hurricane Agnes (1972) in which many people in New York and Pennsylvania were drowned when rivers flooded.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(b) During and after storms, dress warmly, avoid travel, and do not overextend yourself (heart attacks are a major cause of death during and after winter storms).	
(c) Wear multiple layers of protective clothing, scarves, mittens, and hoods. Remember that wind as well as temperature affects the rate at which the human body loses heat. The combined effect of temperature and wind is called wind chill.	*How can the wind chill temperature be calculated? (See Appendix B, page 71* VI *and Appendix C, page 76* IV.*)*
(d) Avoid travel, but if stranded, stay in your vehicle, keep it ventilated, bundle up, stand watches, occasionally change positions, and do not panic.[52]	
2 blizzards	
A blizzard is a severe weather condition in which low temperatures and strong winds bearing a great amount of snow reduce visibility to the extent that travel is nearly impossible.	
Persons stranded in vehicles during blizzards should not attempt to walk to shelter in open areas.	*What are the major causes of deaths in blizzards?*
3 ice storms	
Freezing rain is precipitation that freezes when it hits exposed surfaces. Significant ice accumulation can cause slippery roads, down electrical wires, and snap tree branches.[53]	*What causes the build-up of ice in ice storms?*
Travel by foot or vehicle should be avoided during an ice storm because of slippery surfaces and falling wires.	

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[50] Persons trapped in low-lying coastal areas should evacuate "vertically" if there is no other alternative. The upper floors of substantial buildings might prove to be relatively safe from the storm surge. However, wind effects might cause injuries and deaths.

[51] Flying debris and downed electrical wire are major hazards.

[52] Carbon monoxide poisoning is probably the major cause of death of persons stranded in vehicles during winter storms. A car window should be kept partially open at all times and the car's engine should be used only for short intervals for heating purposes. A car should contain a blanket or sleeping bag to be used if a vehicle is stranded in a snowstorm. The car's ceiling fabric may be used as a blanket in an emergency.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
4 snowstorms and windstorms	
Heavy snowfalls can happen anytime during New York State's autumns, winters, and springs. People should be prepared to spend several days without fresh supplies of food, fuel, and medicines.	
Areas to the lee of Lakes Erie and Ontario are subjected to "lake-effect" snowstorms. In these "snow belts" several feet of snow can accumulate within hours with visibility near zero. Residents and travelers must be prepared for these local, sometimes sudden storms.[54]	*Where are New York's "snow belts"?*
Windstorms, winds of 40 miles per hour for at least an hour, can cause considerable damage. Persons along coastal areas should be alert for possible severe shoreline erosion and flooding. Mobile home dwellers should securely anchor their residences, which are especially susceptible to wind damage.[55]	*What are some examples of destruction due to shoreline erosion?*
F Heat waves	
Periods of at least a day during summer which are abnormally and uncomfortably hot (and usually humid) are heat waves. They can result in heat exhaustion and death.	
The systems of the body must work hard to try to maintain normal body temperature under heat-wave conditions. People should slow down, dress for summer, take in less calories, drink plenty of water, increase salt intake in accordance with personal needs, and probably spend some time in a	*What are the physiological effects of prolonged high temperatures and humidities on the human body?*

[53] Ice storms occur during periods of precipitation when air at above-freezing temperatures overlays a shallow layer of freezing temperatures at the earth's surface. Falling raindrops supercool in the cold air before arriving at ground level, causing ice to build up on exposed objects. The added weight on wires and tree limbs pulls them down.

[54] "Lake-effect" storms occur when cold air flows over relatively warm water surfaces. Heat and water vapor added from the lake below produce the clouds which spew off the ends of the lakes. Snow from these clouds can literally paralyze an area as practically all travel ceases. The "lake-effect" is most pronounced when the cold air blows over the full length of the lake.

cooler environment (such as an air-conditioned room, cellar, or cold bath).

VII. CLIMATE

The climate of a region or place describes its characteristic weather that prevails from season to season and from year to year. Understanding climate is important as it affects all biological processes and human activity.

A Relationship to weather

Climate describes the average condition of the weather. It also includes such statistics as the annual range of temperature and the extreme conditions which are likely to occur in any given period of time.[56]

What is the relationship between weather and climate?

Climate is described in terms of such factors as air temperature, wind, humidity, rainfall, snow, ice, and radiation.[57]

B Classifying climates

While many systems are possible, climate regions are most simply classified on the bases of temperature and moisture conditions.[58]

What factors influence climate? (E-60)

C Climate patterns

The climate of an area is a function of several interacting aspects including latitude, proximity to water bodies, prevailing winds and ocean currents, and altitude.[59]

What are those aspects of your local environment which have impact in determining the climate of the area? (E-60) (E-61)

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[55]Mobile homes, because of their relative lightness and broad sides, can be easily blown over. Mobile home dealers and National Weather Services can offer advice on how mobile homes should be anchored or "tied down."

[56]Climate and weather differ primarily in perspective. Weather is the condition of the atmosphere at a specific time while climate is the history of weather over a period of time. Climate reflects the prevailing characteristics of the weather for a given area.

[57]Statistics are used to determine averages, extremes, totals, ranges, and range characteristics of

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
The climate within New York State varies considerably with location.[60]	
D People and climate	
The economic development of an area is influenced by its climate.[61]	
Climate can be influenced by human activity.	
Energy consumption is closely related to climatic conditions.	*In what ways does climate control the consumption of energy in your locality?*
E Microclimates	
Climates close to the ground show great variability and have great impact on life.	*Where in your environment can you find significant variations in weather elements over short distances?* (E-62)

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different weather factors. Such information is then used to prepare charts, tables, graphs, and summaries. The ways in which specific data are used depend upon the climatological problems being investigated.

[58] Climate classification has been developed in an attempt to systematically divide the earth's climates into different regions. Each region is defined by the relative homogeneity of the criteria used as bases for the classification system.

[59] Comparisons can be made between the climate of different areas based upon the factors that influence it. Appropriate comparisons might include coastal and inland areas at the same latitude, areas on opposite sides of mountain ranges, etc.

[60] New York State is considered as having a humid continental climate with moderate rainfall, hot summers, and cold winters.

[61] Examples can be provided to illustrate how agricultural development is a function of local climate. Industrial development is often influenced indirectly by local climate. Proximity to raw materials is a factor that influences site selection for an industrial plant. Some people choose to live in certain climates for health reasons.

A complete understanding of the complexity of the effect of climate on economic development is beyond the scope of this course and is normally studied in social studies classes. Some simple illustrations will help students to appreciate the significance of climate study.

APPENDIX A - LEARNING ACTIVITIES

E-1. Setting the Stage for "Real-Time" Weather Study (Weather Watch) (1, 2, 3, 12)*

Information gathering is fundamental to weather study. The use of current or recent weather information adds immediacy to the topics at hand and is likely to enhance considerably student interest and involvement. However, the quantity and quality of information to be gathered should be carefully considered to limit what is sought to that which is likely to be used to meet the learning objectives.

Information from beyond the local environment is essential if the beginning student is to have much hope of making sense of direct weather observations. Broad-scale weather information should be acquired and displayed in the classroom. Ideally, weather maps should be on exhibit throughout the year and weather should be discussed whenever outstanding events occur. In fact, many of the basic understandings of weather can be taught informally through the study of weather as it happens.

A place in the classroom should be set aside for the display of current weather information with maps covering two days or more accessible for quick comparisons. Current broad-scale weather information is perishable. The more recent and more accurate the information, the more useful it is. Such information can be acquired in a variety of ways including those which follow. The task can be accomplished by the teacher or students at home or at school depending on interest, time, and access to the information source.

(a) Televised weather information, especially the latest surface weather map, can be obtained from morning television programs. The information can be taped, photographed with an instant camera, copied onto a blank map or, suitably displayed maps can be traced on clear plastic sheeting placed directly on the television screen. Currently, the best source of such information is A.M. WEATHER, an early morning program appearing on local public television stations. Weather maps are also shown on national and local commercial television programs.

(b) In some areas the local NOAA (National Oceanographic and Atmospheric Administration) Weather Radio broadcasts give weather map and other broad-scale weather information. These broadcasts are continuous, plain-language transmissions from local National Weather Service offices. They require a special receiver. One of these radio receivers should be placed in the classroom wherever transmissions can be received as they provide a great deal of information at the user's convenience. In some locations, the broadcasts are relayed on cable television.

(c) Detailed weather information for historical studies of weather (a week or more in the past) and for making up student laboratory exercises can be acquired through a subscription to Daily Weather Maps, Weekly Series available through the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

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*Processes listed on page 7.

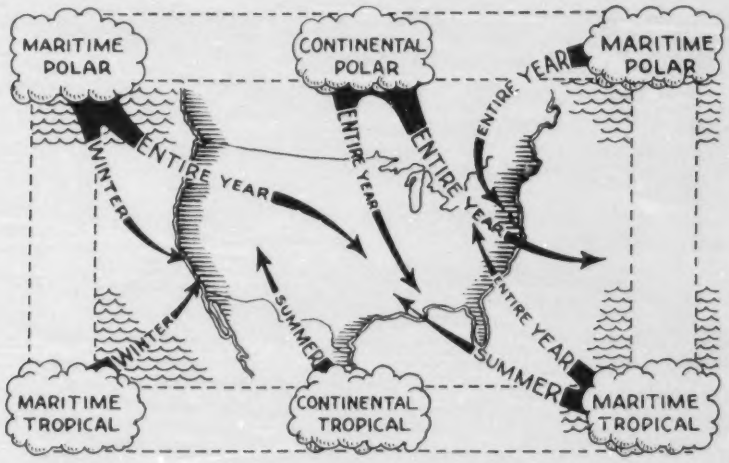
(d) A number of commercial radio stations present comprehensive weather reports which include information on broad-scale weather systems affecting the listening area. These reports can often be taped.

(Caution: Making taped copies of television and/or radio transmissions may constitute copyright infringement. Permission should be requested if material is copyrighted.)

(e) Newspapers can provide useful, although somewhat dated, weather information. Those that feature actual weather maps (rather than the forecast map alone), recent satellite photos, weather information on cities around the country, and hourly weather observations for the previous day are especially useful. They also carry articles which give background on recent dramatic weather and its impacts on people. Special care should be taken not to use forecast maps as though they are maps depicting actual weather.

(f) Schools located near local National Weather Service offices should contact the meteorologist in charge to determine whether or not samples of operational maps can be acquired.

E-2. Identifying Air Masses (19, 17)



(a) A chalkboard diagram or poster similar to the one shown should help pupils learn and remember the main types of air masses, their source regions, and normal paths.

(b) Carefully examine various surface weather maps to find large regions of the map with similar temperature and dew point characteristics. Once the air masses have been identified, classification may be attempted based on the temperature and moisture conditions.

E-3. Air Mass Movement (14, 13, 22)

Examine a series of consecutive surface weather maps. Locate an air mass on the first map of the series. Examine succeeding maps and locate the same air mass on them. Determine the longitude and latitude of the highest

pressure within the air mass on each map. Plot these locations on a blank map and connect the plotted points with as smooth a curve as possible. The lines drawn show the approximate path of the air mass under study. Follow the same procedure with other air masses. What are the general paths which different types of air masses seem to follow? How long does it take an air mass to move across the country? Are the air masses you have studied typical in terms of their motions? Is there any difference in typical speeds at different seasons of the year?

E-4. Locating High (and Lows) on Weather Maps (14, 13)

Copy individual station pressure values from a detailed surface weather map that displays Highs and Lows onto a base map. Ask students to draw specific closed isobars which surround areas of higher and lower pressure. They should then label locations with the highest and lowest pressure values as centers of Highs and Lows.

E-5. Circulation Patterns in High and Low Pressure Areas (14, 17)

Locate areas of relatively low and high pressure on a U.S. Daily Weather Map. Examine the wind directions reported at individual stations located within these areas. Draw arrows with a grease pencil or a felt pen over each station to emphasize the wind direction. Examine the patterns formed by the arrows. How does the surface wind appear to circulate in a high pressure area? In a low pressure area?

E-6. Heating of Air by Compression (1, 2, 17)

When air is compressed, it is heated. The work which is done to compress the gas increases the energy of the gas as indicated by a temperature rise.

Put a finger over the exhaust of a pump used to inflate tires or basketballs. After a few strokes of the piston, note any change in temperature of the cylinder by touching it with the hand.

It may be difficult to convince pupils that the change in temperature is not due solely to friction between the piston and the cylinder. A fire syringe from the physics laboratory or a similar firemaking device obtained from a Boy Scout troop or supply house can be used to ignite tinder by one stroke of the piston. At the appropriate time heating by compression can be used to explain the chinook wind occurring on the eastern slopes of the Rocky Mountains.

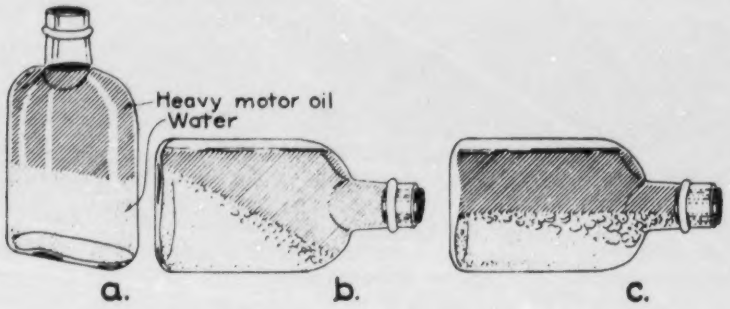
E-7. Cooling of Air by Expansion (1, 2, 17)

When air expands, it does work, loses some of its energy, and its temperature drops. Let air out of an inflated tire. Feel the air as it passes out of the stem.

E-8. How Fronts Form (1, 2, 9)

A rather crude analogy may be helpful in clarifying the meaning of the terms "cold front" and "warm front." Half fill a flat bottle with water and fill the remainder with heavy motor oil (a). Cork the bottle and tip it to one side as shown in (b). The boundary between the two liquids is the "front."

The water represents a cold air mass and the less dense oil represents a warm air mass. Show how the water moves under the oil and how the oil slides over the water. Note the turbulence that occurs along the front in (b) and (c) where the two different fluids are in contact. Discuss the limitations of this simple model.



E-9. Weather Variations in Regions Between Air Masses (14, 15)

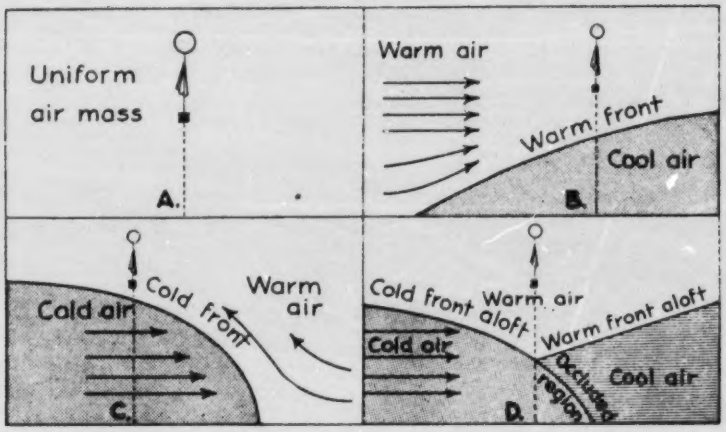
Examine the regions between air masses on several detailed surface weather maps. Compare weather data reported at individual stations along an imaginary line running from the center of one air mass to the center of another air mass. Where do the greatest variations of weather occur along this line? What would happen to the weather at an individual station as the boundary between the air masses passes over it?

E-10. Identifying Fronts (14, 15, 19)

(a) Locate fronts on U.S. Daily Weather Maps. Examine the weather data reported at stations at and on both sides of the fronts drawn on the maps being studied. Study consecutive maps to determine the motions involved and the variations in weather at individual stations. Where are fronts located relative to air masses? What are some of the probable factors determining the intensity of weather along fronts? What kinds of fronts are there?

(b) The use of radiosondes to obtain readings of the temperature, pressure, and relative humidity of the upper air provides important data for weather forecasting. Copy the accompanying diagram (p. 39) on the chalkboard. Discuss the characteristics of the air masses and the weather conditions associated with each front.

Ask pupils to discuss the changes in each of the three factors that would be transmitted by a radiosonde released at point A. After pupils have discussed this normal condition, ask them to predict the changes that would be noticed in the readings measured by radiosondes released from points B, C, and D. Discuss the value of such data in weather forecasting.



E-11. Interpretation of Surface Weather Maps (14)

Collect a variety of weather maps ranging from simplified versions to detailed ones including individual station data. Have students use accompanying keys or legends to interpret symbols appearing on the maps. It is important that map formats from newspapers and television be studied as they are likely to be the students' sources of weather information in later life.

E-12. Sizes of Broad-scale Weather Systems (14, 22, 2, 5)

Provide students with a set of detailed weather maps (with isobars). Have them try to make generalizations concerning sizes of major weather systems and features displayed on the maps. By looking at a sequential series of maps, students might be able to follow the life histories of individual weather systems.

E-13. Interpretation of Satellite Photographs (14)

Acquire satellite photographs and match them with surface weather maps for approximately the same time. Newspapers often publish satellite photos for the previous day. Match these photos with the weather map for the same day. Draw in lightly the locations of fronts and centers of high and low pressure on the photos. Compare maps and photos over a period of days to visualize the movements of weather systems.

E-14. Conducting a Local Weather Watch (1, 2, 4, 5)

In addition to an ongoing weather watch of broad-scale weather systems, it is suggested that students collect local weather data for two weeks or more. By doing so, they are likely to learn more about the different weather variables and relationships that might exist among them.

Activities which follow describe how data for different variables may be collected by direct observations. In areas receiving NOAA Weather Radio transmissions, the data acquired at the local National Weather Service can

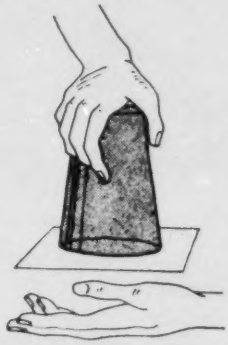
also be compiled by students for analysis. Typically, NOAA Weather Radio broadcasts include hourly updates on weather element observations and climatic summaries for each day. These data can be obtained from a radio receiver located in the classroom and can often be used in place of data that would otherwise have to be obtained through direct measurements. They allow for more efficient use of student time; however, they should not completely replace data acquired through direct observation.

It is recommended that student groups be formed for data collection with tasks being rotated so that each student has an opportunity to make each type of measurement. Also, activities requiring data analysis should be assigned to draw students into active and continuous weather watching.

E-15. Atmospheric Pressure (1, 2)

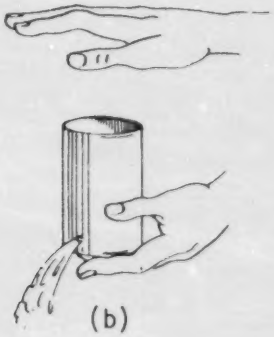
Any of the following activities can be used to demonstrate that air exerts pressure. <u>These activities should not be repeated if the concept of air pressure is familiar to students from earlier studies</u>. Afterwards, students can begin recording atmospheric pressure readings as described in (j).

(a) Fill a tumbler to the brim with water and place a small piece of cardboard over it. Holding this in position with the palm of the hand, invert the tumbler. Then take away the hand.

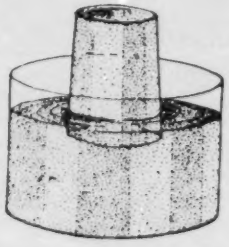


Set the inverted tumbler of water on a smooth table top and slide it off the card onto the table surface. Move it across the table without lifting it. Hold a vessel under the edge of the table and let the water run out.

(b) Make a nail hole near the bottom of a small-sized tin can. Fill the can with water. Hold the palm of the hand tightly over the top of the can and the water will stop flowing from the hole. Lift the hand and the water will start to flow again.



(b)



(c)

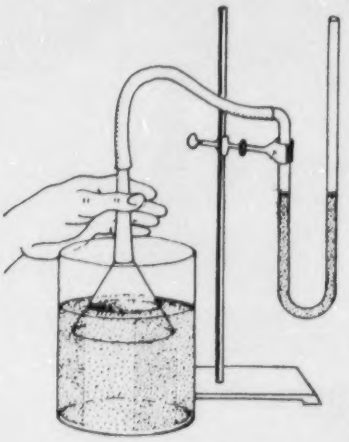
(c) Submerge a tumbler and allow it to fill with water. Turn it to an inverted position and lift it straight up until nearly all of the glass is above the water surface of the jar. The water does not run out of the glass. because of the atmospheric pressure on the surface of the water in the vessel.

(d) Wet the bottom of a sink stopper and press it firmly against some flat surface such as the top of a stool of the bottom of a pail. Then pull upward on the surface of the stopper. List some common devices that operate on this principle.

(e) Wet the bottoms of two plumber's force cups (rubber plungers). Press them together to force out the air between them. Then notice how much force is necessary to pull them apart.

(f) Use a medicine dropper to transfer water from one vessel to another. The dropper fills because the rubber bulb is elastic and tends to resume its original shape after being squeezed. Atmospheric pressure on the surface of the water in the vessel forces water into the dropper.

(g) Make a manometer from a bent glass tube and a rubber tube. Place a little colored water in the glass tube and connect the rubber tube to a glass funnel. Hold the funnel inverted in a vessel of water. Raise and lower the funnel to change the pressure and watch the level of the water in the bent glass tube. (Manometers are used in many common devices to measure pressure.)



(h) If a mercury or aneroid barometer is available students should be instructed in how to read it. Daily readings should be entered into the weather watch log.

E-16. Air Temperatures (1, 2, 14)

As part of the weather watch, students should record air temperatures each day at the same time. An outdoor location should be selected with care being taken that the bulb of the thermometer is shielded from the effects of radiation (especially direct sunlight) and precipitation. If Activity E-17 is performed, the dry bulb reading on the sling psychrometer can serve as the air temperature.

For a few days during the weather watch, students can measure the temperature a number of times during the day starting with early morning and until late afternoon. It can be pointed out from this that, in general, the highest temperatures occur later in the day than when the Sun is highest in the sky. This can be explained by the fact that surface temperatures will continue to rise as long as incoming radiation is greater than outgoing radiation. As soon as the ground radiates more heat energy upward than it receives by sunlight, the temperature will start to drop.

E-17. Dewpoint Temperature and Relative Humidity (1, 2, 5, 14)

Several techniques can be used to determine dewpoint temperature and relative humidity. The sling psychrometer method described in (b) is recommended for the weather watch because of its simplicity and accuracy.

The readings should be taken outdoors because the moisture content and temperature of the air indoors are likely to be different from those outdoors.

(a) The dewpoint temperature may be determined directly by using the "shiny can" method. Half fill a shiny metal can with tap water. Place a thermometer in the water and note the temperature. Slowly add ice to the water, stirring constantly. Note the temperature of the water at the point where moisture first appears on the outside of the can. This is the dewpoint temperature.

The relative humidity can be calculated using the dewpoint temperature and the air temperature and the following formula:

$$\text{Relative humidity (\%)} = \frac{\text{saturated vapor pressure at the dewpoint temperature}}{\text{saturated vapor pressure at the air temperature}} \times 100\%$$

Values for the saturated vapor pressure appear in Appendix B (page 68, III). The following is an example in which the dewpoint temperature obtained is 10° C and the air temperature is 15° C.

$$\text{Relative humidity (\%)} = \frac{\text{saturated vapor pressure at } 10^\circ \text{ C}}{\text{saturated vapor pressure at } 15^\circ \text{ C}} \times 100\%$$

$$= \frac{12.2 \text{ millibars}}{16.9 \text{ millibars}} \times 100\% = 72.2\%$$

(b) Both dewpoint temperature and relative humidity can be determined using a sling psychrometer. After the wick of the wet bulb has been moistened, the psychrometer is whirled until the wet bulb reading stops falling. The difference between the wet and dry bulbs (the wet bulb depression) is calculated and the graph in Appendix B can be used to determine the dewpoint temperature. The relative humidity can be determined by the method described in (a).

Students should be cautioned to be sure that they have a clear area in which to twirl the psychrometer. Contact with objects may break the thermometers.

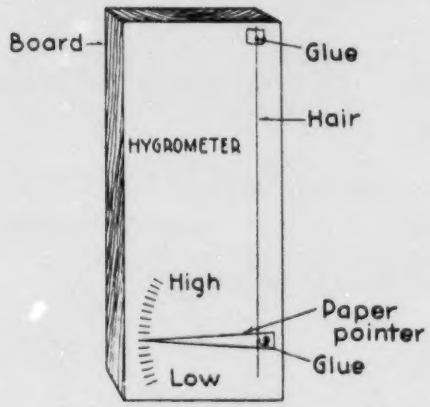
If no sling psychrometer is available, one can be constructed by mounting two thermometers on a wooden board. Fasten a wick (piece of sneaker shoelace) to the bulb of one thermometer using a piece of string or small rubber band. Cut a hole in the end of the board and attach a heavy rope or chain so it can be twirled.

(c) The following two procedures can be used to observe relative changes in moisture from day to day but will not yield values for dewpoint temperature or relative humidity.

(1) Make a hygrometer from a length of human hair. In an area that is well-ventilated, soak a long length of hair in acetone, ether, or gasoline (caution: highly flammable substances) to remove any oil and complete the hygrometer as shown in the diagram. Try the hygrometer outdoors and indoors on the same day.

Keep it in the classroom and note any variations in the humidity from day to day.

(2) Pupils are usually fascinated by color changes caused by the varying moisture content in the air. Dissolve 10 gm. of cobalt chloride in 100 ml. of water. Soak several strips of white cloth or filter paper in this solution. Remove them and allow them to dry. Place strips indoors and outdoors and observe the color changes from day to day.

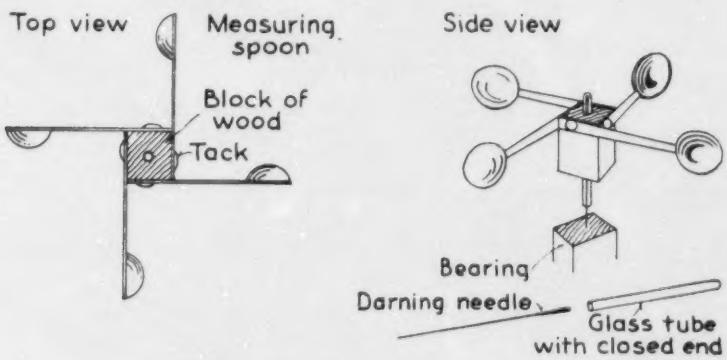


E-18. Wind Speed and Direction (1, 2, 5)

If a commercial wind vane and anemometer are not available, the instruments below can be constructed to obtain data for the weather watch. Rough estimates of wind direction can be made by observing the motion of a flag on a flagpole or the smoke from a burning candle. Wind speed can be estimated using the Beaufort wind scale.

To simplify the weather watch data, wind direction can be described as northeasterly or southerly (or easterly or westerly).

(a) Make a simple anemometer like the one shown in the diagram. Note the behavior of the vanes when the device is held in the wind or in front of an electric fan. Point out that commercial anemometers have a registering device that works like a speedometer on an automobile.



This device will provide relative wind speeds which can be used for day-to-day comparisons.

(b) A very sensitive weather vane can be made from a pencil, soda straw, a pin, and a feather. Insert the feather in the end of the straw and push a pin through the straw into the pencil eraser at the balancing point.

E-19. Cloud Cover (1, 2)

(a) Cloud Type - Most cloud formations can be classified into one of two basic types, cumulus, or stratus. Cumulus clouds are puffy in appearance while stratus clouds appear flat and layered. For purposes of the weather watch, a classification into one of these two categories is sufficient. Another type that does appear is cirrus. This cloud is wispy and can be seen at high altitudes. Pictures illustrating the various cloud types can be found in most earth science textbooks.

(b) Amount of Cloud Cover - The following classification is useful for describing the amount of cloud cover: Clear (0-25%), partly cloudy (25-75%), and cloudy (75-100%). Visual estimates of the amount of cloud cover as well as the cloud type can be made daily and recorded in the weather watch log.

E-20. Precipitation (1, 2, 5)

The amount of rain or snow can be measured by the procedures described below and entered into the weather watch log.

(a) Use a large-size, battery jar or straight-sided, large juice can as the collecting vessel of a rain gauge. To calibrate it with a tall jar of smaller diameter, pour water into the battery jar to a depth of one inch or centimeter. Now pour this water into the smaller jar. Put a rubber band around the smaller jar at the level of the water or mark the level in some other manner. A paper scale may be pasted on the outside of the jar and marked off to represent fractions of an inch or centimeter. Discuss why it is necessary to calibrate the collecting bottle in this manner.

Set the battery jar or can in the open where no building or tree will interfere with the rainfall. After every rainfall, record the amount of precipitation. Compare the results with published rainfall data or that given over NOAA Weather Radio.

(b) If possible, obtain a column of snow from a recent snowfall. The snow column may be cut with a large fruit juice can having both top and bottom removed. Measure the height of the snow and then melt it in a similar can. Measure the depth of the water and determine how many inches of snow equal one inch of water. Repeat the procedure for different types of snow.

E-21. Relationships Among Weather Elements (13, 17)

Comparisons are easily made using two variables at a time. The following are examples of comparisons that can be made:

(a) Do pressure changes correspond to temperature changes? (When the temperature increases, does the pressure increase and when the temperature decreases, does the pressure decrease? Or is the effect opposite? Or neither?)

(b) Is there a relationship between times of precipitation and pressure changes?

(c) Did a particular wind direction (northerly or southerly) relate in some way to temperature, cloud cover, or moisture conditions?

Students should be cautioned not to expect a relationship to exist in all cases because of the interaction of so many variables.

E-22. Effect of Air Masses on Local Weather (22, 14)

Observe local weather conditions when air masses are known to be passing over the area. The latest weather map can be used to determine the general location of air masses. Do the local temperatures and dewpoints vary much during the time an air mass is over our area? How do different types of air masses affect our local weather?

E-23. Observing Approaching Fronts (22, 1, 5)

(a) Watch for the approach of fronts and call pupils' attention to them when they are reported. When the National Weather Service predicts that a warm or cold front is moving in, record the air conditions at that time and then continue observations periodically. As the front passes, continue to make a record of the new air conditions.

(b) Observe the cloud changes as a warm front approaches. First cirrus clouds are observed at high altitudes. These are followed by increasingly dense clouds with lower bases.

Make a chart with chalk on blue drawing paper to show the typical series of clouds as a warm front approaches and passes.

E-24. Locally caused Weather (1, 2, 14)

Environmental factors such as nearby water bodies, topographical relief and human activity can have significant effects on local weather. At times these effects can override the influence of prevailing broad-scale weather systems. Lake or sea breezes, "lake-effect" snowstorms, urban "heat islands," and localized precipitation in mountainous areas are examples. Have students investigate to determine if these or other locally caused weather conditions occur in the immediate geographical area. Do any of these have any significant effect on climate and human activity?

E-25. Making a General Weather Forecast (15, 14, 21)

Modern weather forecasting is accomplished by highly trained meteorologists using sophisticated tools and the latest weather data. However, general weather forecasting can be attempted by extrapolating the movements of current broad-scale weather systems. This is called persistence forecasting. It does not take into account that weather systems and their motions change with time. Students can attempt persistence forecasting with some success if their forecasts are for less than a day ahead. To do so, a sequential set of maps covering the recent past (two or three days) should be examined. Weather systems are tracked by tracing the movements of Highs, Lows, and fronts. The motion is then projected into the near future. (Note: maps such as those available mornings on television should be used for the most recent maps as newspaper maps are too old for this purpose.)

E-26. The Amount of Oxygen in Air (1, 2)

Push a piece of fine steel wool into the bottom of a test tube. Wet the steel wool and invert the tube in a vessel of water. On the following day, note that the water has risen about one-fifth of the way up the tube. This demonstration, which may be done by students on their own, helps them understand the composition of air. (NOTE: The activity may already have been done in the elementary schools.)

E.27. How Living Things Use Oxygen (1, 2, 14)

A wide variety of activities, some of which may be found in the life science blocks (Blocks A, B, C), can be performed to demonstrate how oxygen is used by living organisms. The following are examples:

(a) Ask a pupil to place one end of a rubber tube in his mouth and the other end in an empty bottle such as a quart milk bottle. Have him inhale and exhale several times without removing the tube from the mouth and note the sensation produced by breathing exhaled air. The tube should be of sufficiently large bore, approximately one-fourth inch, to make breathing possible under these conditions.

After breathing into the bottle as described, test the air in it with a burning splint. Since the flame is extinguished, it may safely be inferred that breathing removes some of the oxygen from the air. Tests have indicated that ordinary materials will not burn if the oxygen content of the air is less than 16 percent.

(b) The volume of air inhaled per hour can be estimated quite accurately by each pupil in the following way:

(1) Fill a gallon jug with water and invert it in a larger vessel containing a little water. Exhale through a rubber tube and determine the average number of normal exhalations that will empty the jug.

(2) Determine the average number of exhalations per minute by counting them.

(3) The approximate number of gallons of air breathed per minute is equal to (2) divided by (1).

(4) The number of gallons of air breathed per hour will be approximately 60 times the number of gallons breathed per minute.

(c) Fill two similar bottles with plant nutrient solution. Mixed chemicals for such a solution can be obtained at most florists or "dime" stores. Prepare the solution according to directions on the package. Cut a notch in each of two corks which fit the bottles. Place the stem of a seedling in each of the notches and insert the corks in the bottles so that the roots are in the nutrient solution. Place a rubber tube through the notch of one cork and extend the tube to the bottom of the nutrient solution. Pack each cork loosely with cotton to hold the stems and rubber tube in place. Attach the free end of the rubber tube to an aquarium aerating pump and keep the

solution continually aerated for a week or more. If no pump is available, blow through the rubber tube for a minute or two several times a day.

Note any differences in root development from day to day. Normally, the roots in the aerated solution will show much more extensive growth in two or three weeks than those in the solution that is not aerated. Develop the point that the activities of earthworms and insects in the ground provide openings in the soil for the penetration of air and thus promote better root development of plants.

E-28. Water Vapor in the Atmosphere (5, 6, 14)

(a) The presence of water vapor in the air can be demonstrated by observing either evaporation or condensation. Place a water and ice mixture in a shiny tin can. Observe the formation of droplets on the side of the can. Where must the water have come from?

(b) Closely observe fair weather clouds for evidence of condensation and evaporation continuously taking place along the edges of the clouds. Does this indicate the presence of water vapor in the air surrounding the cloud?

(c) Tie a plastic sandwich bag over a leaf of some house plant. Note that water drops appear on the inside. Transpiration from trees accounts for some of the moisture in the air.

(d) Wet the chalkboard with a damp sponge or paper towel. Watch what happens as the chalkboard dries and discuss what must be happening.

E-29. Evidence of Particles in the Atmosphere (1, 2, 14)

Many direct observations of the atmosphere imply changes in the composition of the air around us. Some of these are due to variations in particulate matter (liquid and solid) in the atmosphere.

(a) Observe the variations in the color of the sky. To imitate what happens to light in the atmosphere, pass a light beam from a filmstrip projector through a small aquarium filled with water. Place a black piece of paper behind the aquarium and observe the beam of light. Add drops of milk to the water until the mixture shows a distinct blue color. Then look through the aquarium along the light beam in the direction of its source.

Describe your observations and attempt an explanation of the changes that occur. Try mixing other substances with the water to see what happens. Apply what you have learned in this experiment to what appears to happen to light in the atmosphere. What do variations in sky color or the color of the moon or sun imply concerning the composition of the atmosphere?

(b) Observe variations in horizontal visibility for several days. What are some probable reasons for these variations?

E-30. Boundaries of the Atmosphere (1, 2, 14)

Fill a glass jar with cold water from a faucet and let it stand for a half an hour or more. Is there any evidence of air in the water, or vice versa? What does this imply concerning the boundary between the atmosphere and the hydrosphere?

E-31. The Layers of the Atmosphere (17, 14)

The characteristics of the layers of the atmosphere are illustrated in the graph in Appendix B, page 68, III. It can be pointed out to students that while atmospheric pressure decreases with altitude, atmospheric temperature varies differently. The graph in Appendix B defines layers based on temperature change with height.

A possible research topic for students would be to use references to determine why the temperature follows the pattern it does.

E-32. Air Pollution (1, 2, 8)

Many concrete examples can be given of air pollution on a small scale. Several such examples should be observed and discussed. Using these examples as a basis, the pupils should be encouraged to discuss the various aspects of pollution on a large scale.

(a) Light a candle and hold a tin can cover or pie plate several inches above the flame. Observe what is deposited on the object held over the flame. What are some of the effects of combustion on the composition of the air?

(b) Open a can of a volatile substance in the classroom. What does the scent imply concerning the characteristics of the air in the room? (Note: Do not use any substance that could cause a health hazard such as carbon tetrachloride. Ammonia and certain room deodorants can be used. Adding a "wick" will speed up the evaporation process if necessary.)

(c) Discuss the exhaust systems of automobiles. What are some of the products of combustion which are given off?

(d) Discuss the hazards of radioactive contamination of the atmosphere. What is radioactive fallout and how is it caused?

E-33. Dust Particles in the Atmosphere (1, 2, 14)

(a) Solid particles in apparently dust-free air may be collected and analyzed. Cover a small glass plate, floor tile, or any such convenient movable surface with a thin layer of a sticky substance such as vaseline, agar, or dessert gelatin. Expose the plate to the atmosphere for a day and then examine the surface under a dissecting microscope. If the exposure is made during warm months, pollen and other organic "dust" will be identifiable on the plate. A surprising quantity of inorganic particles from the seemingly clean atmosphere will adhere to the plate. Vary the height and location of the plate. Carry out the experiment in different seasons. To avoid an incorrect assumption, explain to the pupils that these particles are much too large to serve as condensation nuclei.

(b) Solid particles in the air can be collected on a filter attached to the hose of a vacuum cleaner. Tape or tie a piece of white cloth or paper towel to the open end of a large coffee can. Insert the end of the cleaner hose into a hole cut in the other end of the can. Seal the hose to the can with tape. Expose the end of the can with the filter to the atmosphere and turn on the cleaner. If the hose of the cleaner is removable, the filter may be placed directly over the intake hole. Carefully examine the filter at the end of an hour. Place clean filters on the can and collect other samples of atmospheric particles at different locations on different days. Compare the samples collected.

Interesting experiments can be developed with this apparatus, and techniques of collecting and analyzing particles can be explored. Attempt to determine whether or not there appears to be a relationship between visibility and the number of particles collected, or if the height of the filter above ground level has any effect on the quantity of particles collected. What do these experiments imply as to the kinds and quantities of filterable particles in the atmosphere?

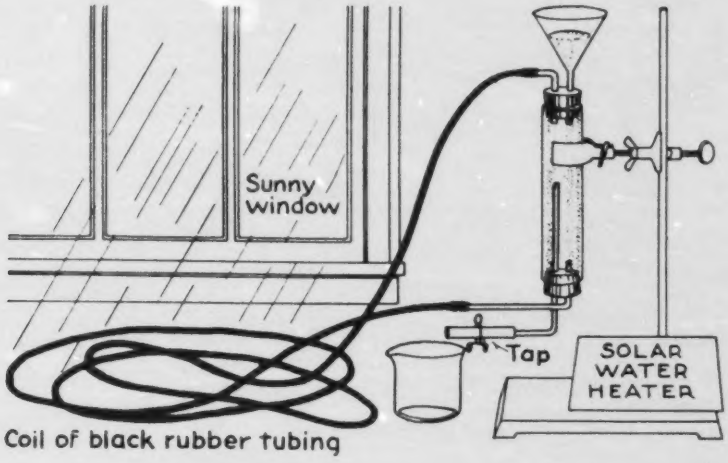
E-34. Natural Atmospheric Contamination (1, 2, 14)

Nature also contaminates the atmosphere, sometimes dramatically. Attempt to find historical accounts of natural contamination episodes (1816 - The Year Without a Summer, Mount St. Helens eruptions, forest fires, etc.)

E-35. Effects of Solar Energy (1, 2, 14)

(a) In introducing a new topic, one way to develop immediate interest is to suggest a simple experiment that every pupil can carry out individually. If the day is sunny, ask pupils to darken one end of a white card by rubbing a lead pencil over it. Then have them place the card in a sunny window for a minute and determine which end of the card feels warmer by laying a finger first on one end and then on the other. The dark end of the card feels warmer because dark colors absorb light and convert some of it into heat.

(b) A working model of a solar heater can be set up in a few moments by connecting a long piece of black rubber tubing to a cylinder of water as shown. The water in the coil of black tubing absorbs energy from the sunlight that comes through the window. It then circulates to the water tank in the shade by convection. Such heaters are common in the sunnier parts of our country.



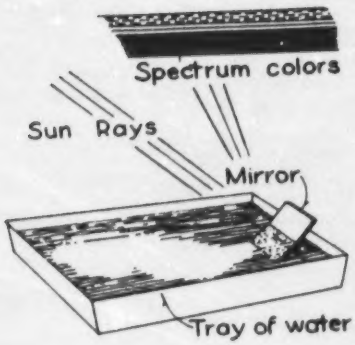
A working model of this kind may be of interest over a period of days or even weeks. Small quantities of hot water can be obtained from the tap on sunny days if the supply tank is kept full. In actual home installations, the cold water pipe is connected to the regular water supply system.

(c) Set a radiometer in direct sunlight and notice how rapidly the vanes rotate. Note the effect of cutting off the Sun's rays with a card or piece of paper. This is direct evidence that sunlight contains energy. As an alternative to this, the following can be done:

TEACHER DEMONSTRATION ONLY: Blacken the bulb of a thermometer by dipping it in India ink several times or by painting it. Place the thermometer inside a bell jar so that its bulb is hanging freely. Evacuate the bell jar with a vacuum pump. CAUTION: Place a towel or other protective device around the jar while removing the air. Read the thermometer while the bell jar is in a shaded location, and then place the bell jar in direct sunlight. Read the thermometer again after several minutes. Why did the temperature reading rise? How is the heat energy transferred to the thermometer? Does the earth receive energy from the sun in the same way?

E-36. Nature of Solar Energy (1, 2, 14)

(a) Set a tray of water in bright sunlight. Lean a rectangular pocket mirror against an inside edge and adjust it so that a spectrum appears on the wall. (It is usually best to avoid going into the theory of refracted light at this point because most junior high school pupils are not ready for it. They will be interested, however, in the fact that all the colors are present in sunlight. Prisms, whether of glass or of water, separate these colors into a bank that we call the color spectrum.)



(a)

(b) Allow a narrow beam of sunlight to fall on a glass prism so that the band of colors that is produced falls on the wall, ceiling, screen, or a white card held nearby. This band of colors consisting of red, orange, yellow, green, blue, indigo, and violet is known as the spectrum. White light is really a mixture of these seven colors. Different wavelengths of light (colors) are bent differently as they pass through the prism. Red is bent the least, violet the most.

Similar spectra are produced when light passes through diamonds or cut glass. A rainbow is caused by sunlight being broken up into its colors after being refracted and reflected by raindrops.

E-37. Rate of Energy Absorption (1, 2, 14, 17)

(a) Measure the air temperature two inches above various level ground surfaces. Be sure the thermometer is shielded from direct sunlight and that the air is relatively calm. The measurement should be taken in a region which allows the moving air to pass over the same type of surface for at least 30 meters before reaching the thermometer. Measure the temperature of the air at other heights over the same surface. Over what kinds of surfaces are the temperatures highest? Lowest? How do temperatures two inches above ground level compare with temperatures several feet above ground level?

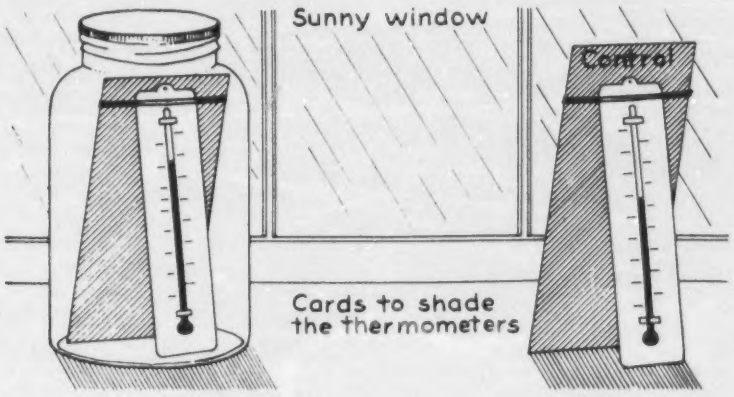
(b) Staple or glue pieces of aluminum foil, black cloth, glossy paper, sand paper, etc., to different blocks of wood of the same size. Hang with string from a cardboard disk a thermometer from which the bottom of the backing has been removed to allow the bulb to be completed exposed. Place it in a mailing tube that is just wide enough for the thermometer to hang freely inside. Cut off the bottom of the mailing tube so that the thermometer bulb is 1/2 cm from and above the bottom rim. Cut a slot in the side of the tube wide enough and long enough so that the thermometer scale can be read. Cover the slot with transparent tape.

Place a 150-watt bulb at a distance of one inch above the middle of one of the prepared blocks for five minutes. Remove the light and place the mailing tube with the thermometer over the block. Read the temperature every 1/2 minute for three minutes. Repeat with the other blocks. What type of surface causes the thermometer to rise the most? Is the air warmer

over dark or over light surfaces? Is the air warmer over rough or smooth surfaces? How are these observed conditions related to the atmosphere in general?

E-38. The Greenhouse Effect (1, 2, 14)

Set up a "heat trap" as shown in the diagram to illustrate the principle of the greenhouse, cold frame, or solar house. The shorter infrared radiation from the sunlight passes through the glass and heats up the material inside. The longer heat waves that are reradiated cannot get out through the glass, hence the temperature rises.



Compare the results with how the atmosphere "traps" energy radiated back by the earth.

E-39. Loss of Heat Energy to the Earth's Surface (1, 2, 5, 14)

The atmosphere at times loses heat to the earth's surface. Place a water and ice mixture in the bottom of a large glass jar or beaker. Place a piece of cardboard over the jar. Punch two holes in the cardboard and insert two laboratory thermometers through the holes so that the bulb of one is about one inch above the ice and water and the bulb of the other thermometer is about six inches above the surface. Hold the thermometers in position with masking tape. Read and record the temperatures observed every five minutes for about a half an hour. What happens to the temperature of the air within the jar? Where is the energy going that the air is losing? Have you observed similar happenings in the free atmosphere?

E-40. Energy Balance (1, 2, 14)

Place the blackened bulb of a thermometer several inches away from the light bulb of a three-way lamp. Support the thermometer with a stand so that its bulb is at the same height as the light bulb and so that its position relative to the light source does not change. Turn the light on to its dim position and observe the temperature of the thermometer. (CAUTION: If the thermometer heats up too much, move it further away from the light.) After the thermometer has maintained a constant temperature for several minutes, turn the light switch to the middle position. Note that the thermometer eventually registers a constant but higher temperature. Turn

off the light and observe the temperature of the thermometer. Repeat the experiment after carefully removing some of the material used to blacken the thermometer bulb. When did the thermometer lose as much heat energy as it gained? Why did the temperature always assume a constant although different temperature after the conditions of the experiment were changed? What does this experiment lead us to conclude about the energy balance of the earth and its atmosphere?

E-41. Angle of the Sun's Rays (1, 2, 14)

The higher the Sun is in the sky, the more concentrated are its rays striking a horizontal surface. This can be demonstrated by projecting a 35-mm. slide made with a piece of window screen onto a globe. Since the amount of light passing through each square of the window screen is the same, the more spread out the light is on the globe's surface, the less concentrated it is.

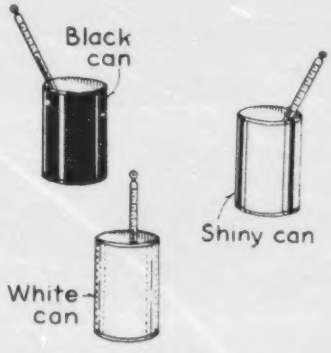
E-42. Factors Affecting Heating Rates (1, 2, 14)

(a) Place a thermometer with a blackened bulb in various locations such as in direct sunlight, shaded from direct sunlight but exposed to sunlit surfaces below, and completely shaded above and below. Vary the surfaces over which the thermometers are located and vary the time of day at which observations are made. In which location and at what time of the day does radiation appear to have the maximum effect on the thermometers? Does a thermometer shaded from direct sunlight but exposed to surfaces below indicate higher temperatures than a thermometer in the same location but shaded from the surface below as well as from direct sunlight? What does this imply as far as radiation from the ground is concerned?

(b) With a photographic light meter, take a reading of the light energy from the Sun's rays reflected off an object outdoors in early morning and at noon. Record the lightmeter reading and draw conclusions.

(c) With the room darkened, allow the beam from a flashlight to fall perpendicularly on the blackboard or some other surface from a distance of a few feet. Now, from the same distance, allow slanting rays from the flashlight to fall on the same surface. Notice the much greater area covered by the slanting rays and the resulting decrease in the intensity of illumination. Relate this to the actual situation that prevails in the northern hemisphere during the summer and during the winter.

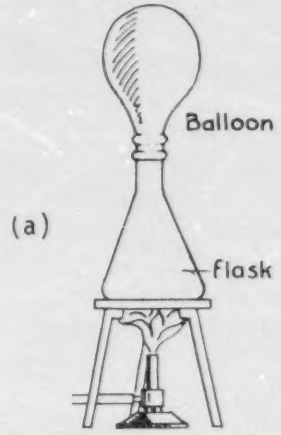
(d) Show how the absorption of radiation varies with the color and nature of the surface on which solar energy falls. Obtain three similar tin cans and paint one black. Paint another white and leave the third unpainted. Put a styrofoam cover on each can with a thermometer inserted through it. Set the cans at equal distances from a light source (150-300 watt bulb). Prepare a table for data and record the temperature of the water in each can at one-minute intervals. Relate the results to the unequal



absorption of heat by different land and water surfaces and to the microclimates of certain restricted areas. (NOTE: Either the shiny or the white can may be omitted.)

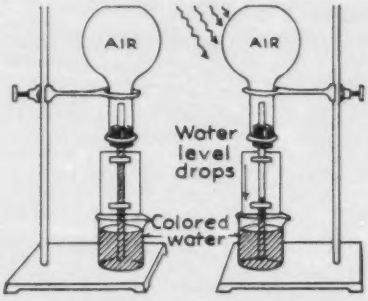
E-43. Relationship Between Air Temperature and Pressure (17, 1, 2)

(a) Attach a toy balloon to a narrow-necked can by pulling the nozzle of the balloon over the neck of the can. Heat the can over a candle. Does the balloon become inflated? What happens to the air in the can? Why does some of the heated air flow into the balloon? Was it pushed? (NOTE: A flask and burner may be used in place of the can and candle if heated gently - see diagram.)



(b) Inflate a balloon and release the nozzle. What happens to the air in the balloon when the balloon is opened? Why does the air rush out of the balloon? Is there a pressure gradient involved? (The difference in air pressure over a unit distance is called a pressure gradient.)

(c) A simple air thermometer like the one shown in the diagram illustrates the relatively greater expansion and contraction of gases with changes in temperature as compared to liquids. Heat the flask gently with the palms of the hands to drive out a few air bubbles, then let the bottle cool. Note the behavior of the liquid in the tube when the flask is warmed.



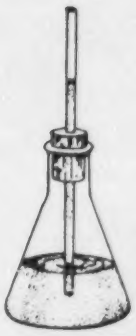
Invite suggestions for calibrating an air thermometer. Discuss the advantages and disadvantages of this type of thermometer.

(d) Tie strings around the necks of two large flasks. Suspend the flasks from each end of a yardstick or meter stick. Suspend the center of the stick from a support and find the point at which the flasks just balance each other.

Now heat one of the flasks with the flame of a burner. This will expand the air and drive some of it out of the flask. The air in the heated flask will then weigh less than the air in the unheated flask and the flasks will no longer balance each other exactly. Try to bring them back into balance by heating the other flask.

(e) Wet the end of a long glass tube and fit it into a one-hole stopper. Insert the stopper into a glass flask. Invert this and immerse the lower end of the tube in a vessel of colored water. Heat the flask by holding it between the hands to force out some of the air. When the air cools again, some of the colored liquid will rise in the tube. An air thermometer tube may be used if one is available.

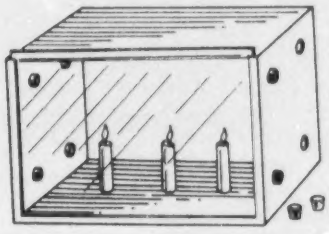
(f) Put a little colored water into a small flask. Insert a long tube through a one-hole stopper to the bottom of the flask. The level of the liquid can be adjusted by blowing in a bubble or releasing the stopper to let air out. Warm the flask and note the change in the level of the liquid within the tube. Cool the flask and note what happens.



E-44. Convection Currents (1, 2, 14)

Experiment with a ventilation box. If no such box is available find or make a wooden box about 25 cm high and about the shape of an ordinary room. Bore four holes in each end to fit large corks. Light three candles inside the box and fasten a large piece of glass over the open side.

To trace the air currents in a ventilation box a source of smoke will be needed. There are ways to make chemical smoke safely but a stick of punk or a smoking piece of facial tissue or paper towel will work equally well. If tissue or towel is used, roll up a piece and light it with a flame.



(a) Remove one cork at the top of one side. Insert the source of smoke into the hole and note the direction of the air current.

(b) Remove the corks at the bottom of one side and notice the currents.

(c) Remove corks from the top and bottom of the same side. Hold the source of smoke just outside and just inside of each of the holes.

(d) Remove corks from the top of one side and the bottom of the other side to study the currents. Apply the observations made to the problem of ventilating a room.

E-45. The Coriolis Force (21, 2, 14)

(a) The deflection of winds due to the rotation of the earth can be demonstrated by mounting a circular piece of cardboard with a diameter of about 18 inches to a slender stick with a small nail passing through the center of the cardboard. The cardboard and stick should be loosely held against the chalkboard with the stick in a horizontal position on the side of the cardboard away from the board. Draw stars on the blackboard.

If the cardboard is thought of as being the Earth as viewed from above the North Pole, rotation can be simulated by having a pupil slowly turn the cardboard in a counterclockwise direction. A moving parcel of air can be represented by a piece of chalk held on the cardboard next to the stick. While the cardboard is being rotated, move the chalk outward from the center of the cardboard along the stick. It will be observed that although the chalk moved in a straight line relative to the stick and the "stars" on the chalkboard, it moved along a curved path relative to the cardboard.

Follow the same procedure, but move the chalk inward from the edge of the cardboard towards the center. If the cardboard were the Earth, and if you were standing where the chalk was initially, how would the motion of the chalk appear to you? Did it appear to be deflected towards the right in both cases? How can an object move in a straight line and along a curved line at the same time? (Motion is relative. It depends upon your frame of reference.)

Deflection of winds to the left in the Southern Hemisphere can be illustrated by rotating the cardboard in a clockwise direction and by assuming that you are looking down at the South Pole. Follow the same procedure with the chalk as before.

(b) The deflection of winds can be best explained if there is a children's merry-go-round available on the school's playground. Have two pupils ride the merry-go-round at a time and have them toss a softball back and forth as the merry-go-round is slowly rotated. They should be able to observe the apparent deflection of the ball when they use the merry-go-round as their frame of reference. However, if they use the ground as their frame of reference, they will notice that the ball is moving in a straight line as viewed from above. By assuming that the ball is a parcel of air and the merry-go-round is the Earth as viewed from above one of the poles, it is possible to illustrate the deflection of moving air as it travels across the Earth's surface.

E-46. General Atmospheric Circulation (19, 14)

In discussing atmospheric circulation and air masses, chalkboard or slated maps and "slated" globes (any globe which can be marked with chalk) are particularly useful in locating with a soft greaseless chalk the planetary wind system, ocean currents, air mass source regions and their paths, isobars, and isotherms.

The chalkboard map of the world can be profitably used in discussing such phenomena (and their causes) as:

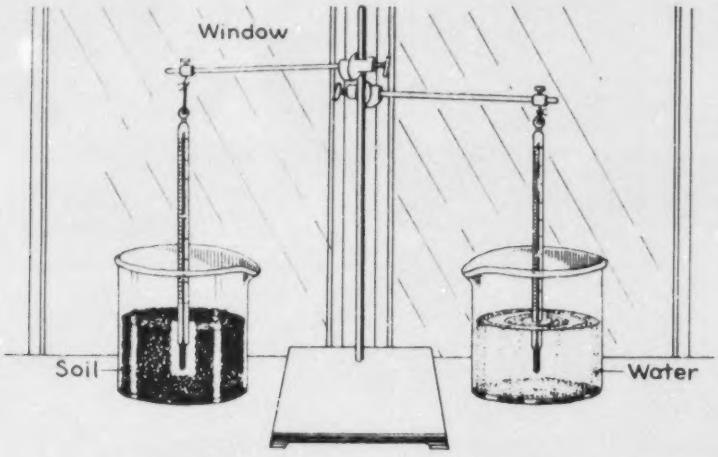
- the continuity of pressure belts in the Southern Hemisphere and the lack of continuity in the Northern Hemisphere
- the migration of pressure belts with seasons
- monsoons of India and of the Southeastern United States
- the isobar and isotherm pattern in each hemisphere in a "summer" and "winter" month (Isobars and isotherms are lines joining points of equal pressures and temperatures, respectively.)

E-47. Heating Rates of Land and Water (1, 2, 14)

To show the unequal heating of land and water, place some soil in one beaker and fill the other to the same level with water. Allow the containers to remain in a shaded place until their temperatures are the same. Then set the beakers in direct sunlight (or 100 watt bulb with reflector). Support a thermometer in each dish with the bulb just covered.

Read the thermometers every ten minutes during a class period and determine which gains heat faster. Relate the results to the development of land and sea breezes.

This process can be speeded up by substituting a light source for the sunlight and taking readings every minute for ten minutes.



E-48. Evaporation and Transpiration (1, 2, 14)

(a) Measure out 50 milliliters of water with a graduate and pour it into a vessel of much larger diameter than the graduate. Again measure 50 milliliters of water and allow it to remain in the graduate. On the following day, measure the amount of water in each vessel again and relate the amount of water that has evaporated to the surface areas exposed.

(b) Put equal amounts of water into two similar vessels. Set one vessel in the coolest place in the room and the other in the warmest place. On the following day measure, with a graduate, the water remaining in each place.

(c) Place a flower pot full of moist soil on one platform of a beam balance. Balance it with weights on the other platform. After a day notice that the soil weighs less than it did originally. Evaporation of moisture from the soil accounts for a large amount of moisture in the air.

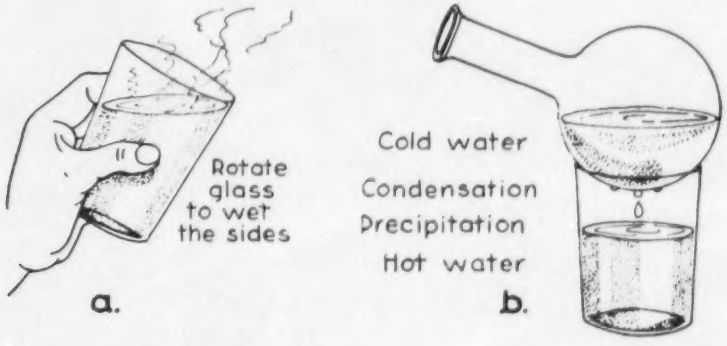
(d) Completely cover the soil of a potted plant with plastic. Then place the plant under a large glass jar. Over several days, note the moisture collected on the inside of the jar. The moisture transpired from the leaves.

E-49. Condensation and Sublimation (1, 2, 14)

(a) Pour ice and water in a metal can. If the humidity is not too low, moisture will collect on the can. Since the moisture cannot go through the can, it must come out of the air. Record the temperatures of the ice water when the dew appears on the can. This is the dewpoint temperature.

On a very dry day there may be too little water vapor in the air for any to condense on the cold surface of the can. If this happens, set the can of water and ice in a battery jar with a moist blotter in the bottom and cover the jar with a pane of glass. Refer also to Activity E-17, part (a).

(b) Heat some water until it is near the boiling point. Pour the hot water into a drinking glass until it is about two-thirds full and rotate the glass so as to wet the sides all the way to the top. Now put some cold water into a Florence flask and set the flask on the glass at an angle as shown in the diagram.



Water will evaporate from the surface in the glass and condense on the cold flask. Drops of the condensed water will continue to fall back into the glass for many minutes. This demonstration makes an extremely simple approach for developing the concept of the water cycle. Evaporation, condensation, and precipitation proceed inside the glass just as they do in the outside world.

(c) Put a wet blotter in a large glass vessel such as an empty aquarium. Cover the vessel. In a few hours the humidity of the vessel will be high. Place a small can of cold water in the vessel and note the condensation. Use a similar can of cold water outside the vessel as a control.

(d) Place an ice cube on the shelf in the freezer compartment of a refrigerator. Observe the decrease in size of the ice over several weeks even though no melting is occurring. Snow, ice, and frost will disappear in nature even when the outside temperature remains below freezing.

(e) Place a thick-walled, clear-glass jar in the freezer compartment for several hours. Remove to the room (or a humid environment such as described in (c) above. Note the formation of rime ice (frost).

E-50. Air Saturation (1, 2, 14)

(a) Put a hygrometer in a large covered battery jar which contains a piece of wet blotting paper. Warm the jar, then cool it. If the air is saturated, the wet and dry bulb readings should be the same at any temperature. Discuss the reason for this.

(b) Obtain a clean, dry flask and put it in a cold place. Blow into the cold flask through a glass tube until a film of moisture forms on the inside. Then stopper the flask tightly and warm it very gently. Observe what happens to the film of moisture. Again place the flask in a cold place and observe it periodically. Refer also to Activity E-30.

E-51. Condensation Nuclei (1, 2, 14)

Use the smoke from a match to "seed" the air within a jug as shown in the diagram. Next, blow into the jug several times to raise the

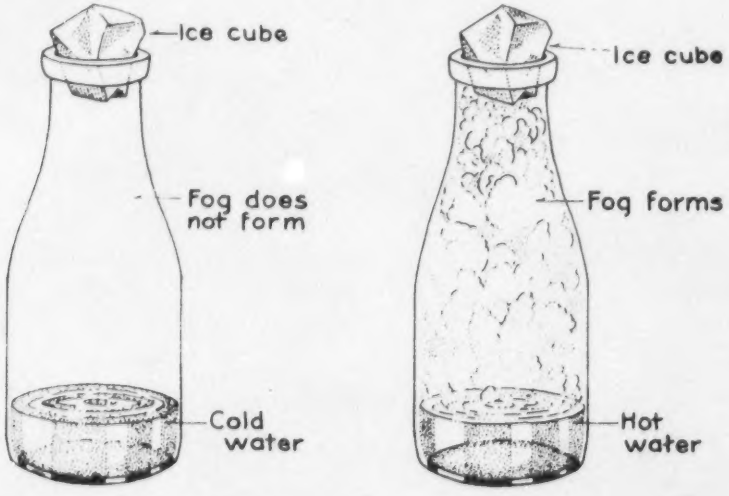
relative humidity. This, together with the suspended smoke particles, creates ideal conditions for condensation. Now, place the mouth of the jug against the lips; blow hard and release the pressure suddenly. The sudden release of the pressure cools the air slightly and a thick fog forms.

Blow into the jug again and the fog disappears. It reappears when the pressure is again released.

Try the same experiment without seeding the air in the jug with smoke particles.

E-52. Cloud and Fog Formation (1, 2, 14)

Fill a milk bottle with hot water. Then pour out most of the water, leaving about an inch in the bottom. Place an ice cube on the mouth of the bottle as shown in the diagram. Set up a control, using cold water instead of hot. Ask pupils to explain why the fog forms in one bottle but not in the other.



E-54. Measuring Raindrop Diameters (1, 2, 14)

A realistic measurement of raindrop diameters can be made by stretching a piece of nylon stocking over an embroidery hoop and sprinkling the fabric with powdered sugar. To obtain a sampling of raindrop sizes hold the hoop

horizontally for a few seconds in the open during a period of rainfall until a number of raindrops have passed through the hoop. Quickly cover the hoop to prevent overlapping of raindrop patterns. Indoor examination of the fabric will show markings in the sugar indicating where the drops passed through the fabric. The diameters of these patterns are nearly the same as the horizontal diameters of the drops. What is the average diameter of the drops sampled? What were the extremes in diameters measured? If you assume that raindrops are spherical (they are not, but nearly so), what would be the average volume of the drops measured? How does the average size of the raindrops sampled compare with the size of the cloud droplets formed in Activity E-52?

E-55. The Hydrologic Cycle (14, 1)

Most earth science textbooks contain charts of the water or hydrologic cycle that can be used for illustration purposes.

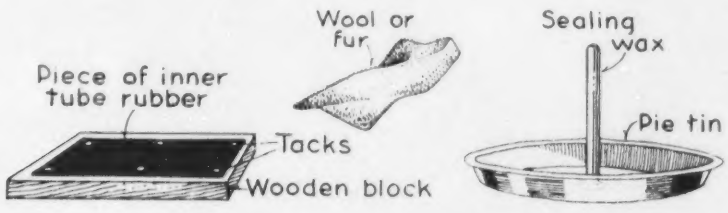
A closed terrarium can be used to illustrate a portion of the cycle. Transpiration from the plants and evaporation from a dish of water in the terrarium cause the air inside to become saturated.

If ice cubes are placed on top, condensation will occur. Excess moisture along the sides may run down to the soil, representing precipitation. If the ice cubes are removed and replaced by a light source (representing the Sun), then the excess moisture will again evaporate.

E-56. Lightning

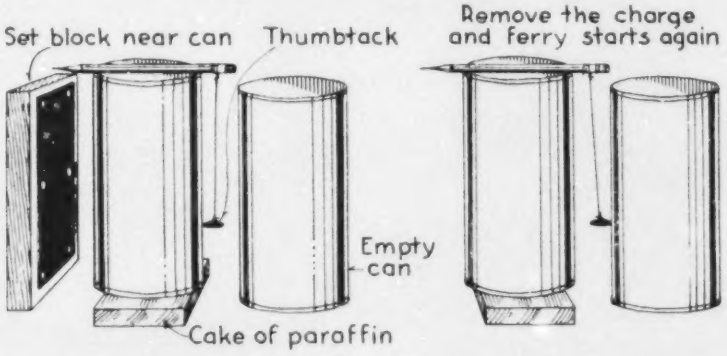
(a) Make a simple electrophorus to show how electric charges, such as those built up in clouds before thunderstorms, may be produced by induction. Cut a piece of inner tube about six inches square and tack it to a wooden block. Obtain a small pie tin and a stick of sealing wax. Melt one end of the stick of wax and force it against the inside of the pie tin to make an insulated handle as shown in the diagram. Briskly rub the piece of rubber with wool or fur to give it a charge. Set the pie tin on the charged rubber, touch the inside of the tin for an instant, and then pick up the plate by means of the insulating handle. The pie tin now has a charge.

Bring the pie tin near a pitch ball to show that the tin has a charge. Now hold it near a metal faucet or radiator. The spark that jumps across the gap usually looks like a miniature flash of lightning and, like thunder, it can be heard.



(b) Make an electron ferry from two metal cans to demonstrate electrostatic induction. Place the cans side by side and set one on a cake of paraffin. Hang a thumbtack from a thread between the cans as shown in the diagram. Adjust the support so that the thumbtack is just touching the side of the insulated can.

Now charge the piece of rubber used in (a) and set the block near the insulated can. As electrons are repelled by the rubber, the tack becomes negatively charged and is repelled. When the tack touches the uninsulated can, the tack loses its charge and swings back. Thus, as the cycle repeats itself, the tack ferries electrons to the uninsulated can. When the ferry stops, it can be made to start again by removing the rubber. Since the uninsulated can is now positively charged, electrons are now ferried in the opposite direction until the can is again neutral. Point out that charged clouds induce opposite charges on the earth beneath them. Discuss the role of lightning rods in neutralizing these charges.



(c) Photographs or slides of lightning can be easily taken during nighttime thunderstorms if a camera is available with a setting for time exposures. During periods of lightning, aim the camera shutter in the direction in which lightning most frequently occurs. Hold the camera shutter open until lightning has occurred in the field of view. Results will be best if relatively slow film is used and if the field of view is free of extraneous light. The photographer should be located in a safe location, such as an automobile or porch, during this activity. Examine the slides or photographs to determine the general characteristics of lightning. Does lightning always occur between a cloud and the earth's surface?

E-57. Thunder (1, 2, 14)

Hold a thin piece of paper, such as carbon paper, next to a metal faucet or radiator. Bring an electrically charged object, such as a pie plate as described in Activity E-56, near the grounded object so that a discharge occurs through the paper. Listen for the noise during the discharge. Carefully examine the paper. What does the small hole burned through the paper indicate concerning the temperature of the region where the discharge took place? What relationship is there between the high temperature that must have been present and the noise? Is thunder formed in this way?

E-58. Tornadoes (1, 2, 14)

The following is a description for the construction of a vortex generator which demonstrates how tornadoes form. In the model, the Northern Hemisphere is simulated by opening all the sides on the right. This produces a torque which spins the rising, warm, moist air in a counterclockwise direction. By sliding all the sides to the right so that the openings are at the left, the clockwise rotation in the Southern Hemisphere can be demonstrated.

The energy which drives this model is quite similar to that of a hurricane. Much of it comes from the heat of condensation released when the water vapor condenses to form the cloud. A much smaller part comes from the vapor which was warm to start with. An even smaller part comes from the saturated air which is less dense than dry or unsaturated air (average molecular weights). This warm air is lifted (Archimedes' Principle) by the heavier cool air rushing into the opening along the sides. This air in turn is heated by condensing water vapor and the process becomes continuous. The arrangement of the opening produces the rotation.

In nature, winds with a north-south component in their direction have a tendency to curve to the right in the Northern Hemisphere and to the left in the Southern Hemisphere when they are approaching a low pressure area. This is due to the fact that the atmosphere moves along with the earth in its daily rotation eastward. The air at the Equator is moving fastest in this respect (over 1,000 m.p.h.) and this speed decreases pole-wards to 0 m.p.h. at the poles (in reference to space). Air moving northward in the Northern Hemisphere is therefore moving eastward faster than the area into which it moves. This means that it curves to the right. Air moving northward in the Southern Hemisphere lags the area into which it is moving - hence, it curves to the left. Similarly, southward-moving air curves to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This creates the cyclonic motions of air masses about lows in the Northern Hemisphere (counterclockwise) and in the Southern Hemisphere (clockwise).

MATERIALS LIST

4	2' length of 1" angle iron or aluminum
2	16" x 16" x 3/8" pieces of plywood
4	4-1/2" x 14-1/2" x 3/4" pieces of plywood or cratewood
4	4-1/2" x 16" x 3/4" pieces of plywood or cratewood
4	porcelain sockets-standard 110 volts
4	25-watt incandescent lamps
1	12" aluminum pizza pan (Mirro has one with a beaded edge and bevelled sides which seems ideal for this purpose - a hardware store item
15	pieces of 14" 1/4 round (1 piece of 1/4 round is omitted at the outside lower area of the Masonite section)
3	14" x 20" double weight glass (standard size, needs no cutting)
1	14" x 20" Masonite
1	20" x 1-1/4" x 3/16" strap iron (to make 4 corner pieces for adjustable legs)
4	4" x 3/8" bolts (adjustable legs)
24	1" round head screws

24	1" flat head screws
1	section 6" stove pipe 30 inches long (standard hardware item)
3	1" x 1" right angle braces (used as stops on stove pipes)
1	utility box-electrical 2" x 4" x 1-1/2" with cover
1	1/4 pt. dull black paint
1	1/4 pt. waterproof sink paint
1	electric hot plate 600 to 1100 watt (tubular type preferable)
2	drawer pulls - useful in handling the apparatus

CONSTRUCTION HINTS

1. None of the dimensions are critical. They may be varied to fit materials on hand.

2. The inside top should be painted white or aluminum - other parts black.

3. The quarter-rounds are used to make guides for the sliding sides at both top and bottom as near the outside edges as possible.

4. The quarter-rounds can be spaced easily by using a narrow strip of wood slightly thicker than the glass. A piece of ordinary yardstick works well.

5. If the three bottom outside quarter-rounds are fastened with small screws, the placement and replacement of glass is much easier.

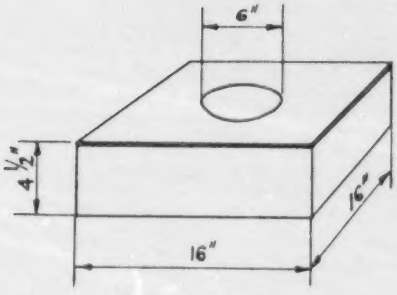
6. The ventilating holes are important and should be as near the top of the bottom space as possible. Seven 1/2" holes on two sides are adequate with an 1100-watt hot plate.

7. The wiring can be more elaborate. Switches can be put in both circuits and arrangements for coiling the lead line can be made under the frame. This lead should be no. 14 wire if an 1100-watt heater is used. No. 16 will do for a 600-watt heater.

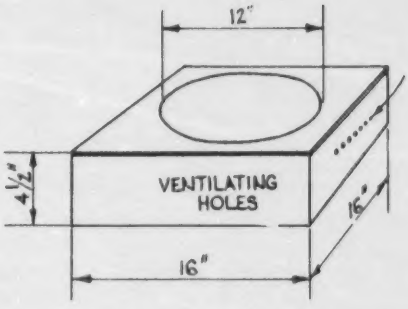
8. The water container may be made of sheet metal to fill all the space inside the frame and be approximately two inches deep. This will then hold enough water for all day displays without frequent inspection and produce more vapor and a more visible funnel.

9. A small knob near the bottom of the Masonite makes access to the interior much easier.

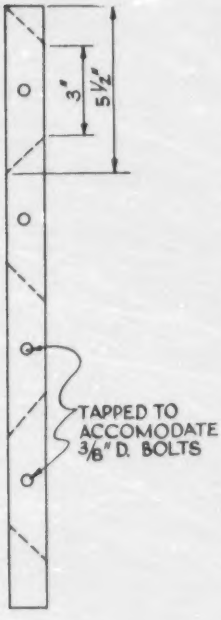
Vortex generator



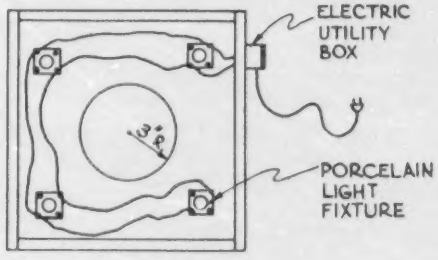
UPPER WOODEN BOX



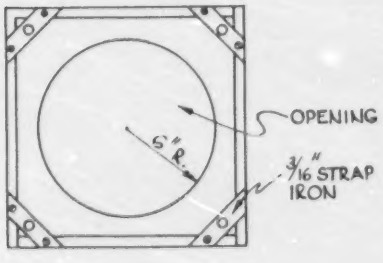
LOWER WOODEN BOX



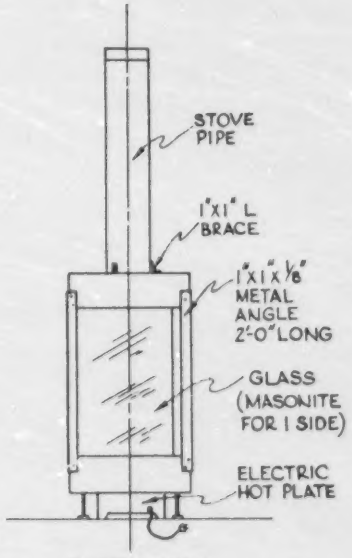
STRAP IRON PATTERN



VIEW INSIDE UPPER WOODEN BOX



VIEW INSIDE LOWER WOODEN BOX



SIDE VIEW

E-59. Tracking Hurricanes and Tornadoes (14)

Whenever tornadoes or hurricanes occur in or near the United States, the teacher should collect a series of U.S. Daily Weather Maps covering the periods when such events take place. The series can then be studied at the appropriate times by students. To promote student interest, a file of newspaper clippings should be kept for reference. The periodical Weatherwise often has articles covering such events.

E-60. Regional Climate (17, 13)

Provide students with a map of the United States that shows the bodies of water and the mountain ranges. Have them sketch the prevailing wind pattern on their maps as well as the direction of ocean currents along both coasts.

Provide students with climate data (temperature and precipitation) for several pairs of cities and have them account for similarities and differences. Among the possible pairs would be two cities on opposite sides of a mountain range, a coastal city, and an inland city at the same latitude, etc.

E-61. New York State Climate (17, 14)

Compare the climatic conditions in various areas of New York State. Call attention to the geographic features that influence local conditions. Many areas are greatly affected by nearby bodies of water, such as those east of Lake Erie, south and east of Lake Ontario and around Long Island. Other areas, such as the Allegheny Plateau, the Catskills, and the Adirondack Mountains, have climates that are influenced by altitudes.

Daily radio and television roundups and weather maps give further evidence of the varying conditions over the State. A map showing the length of the growing season in various parts of New York State can also be used to show variations in climate.

E-62. Investigating Microclimates (11, 12, 14)

The concepts of climatic conditions and the factors that influence climate can be approached through the first-hand study of microclimates. Locations can usually be found in areas near any school where there are pronounced differences in the average temperature, moisture conditions, amount of sunlight received, and in the plant and animal life.

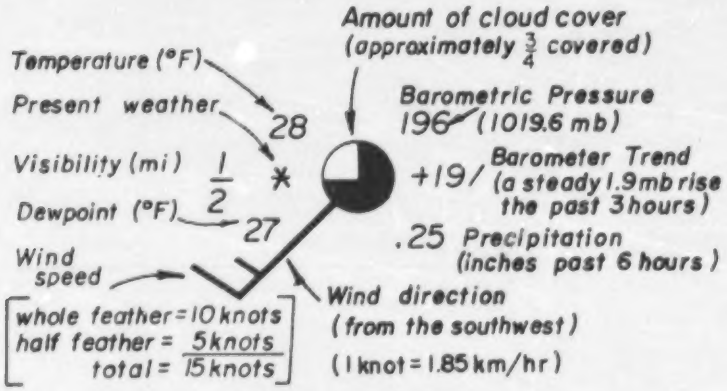
Even a comparison of the conditions on the north and south sides of the school building will reveal climatic differences.

APPENDIX B – CHARTS, TABLES, DIAGRAMS

I WEATHER MAP INFORMATION

WEATHER MAP INFORMATION

STATION MODEL



AIR MASSES

cA Continental arctic

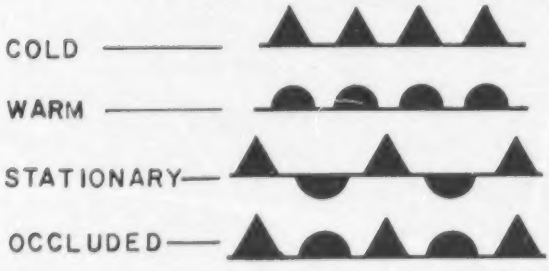
cP Continental polar

cT Continental tropical

mT Maritime tropical

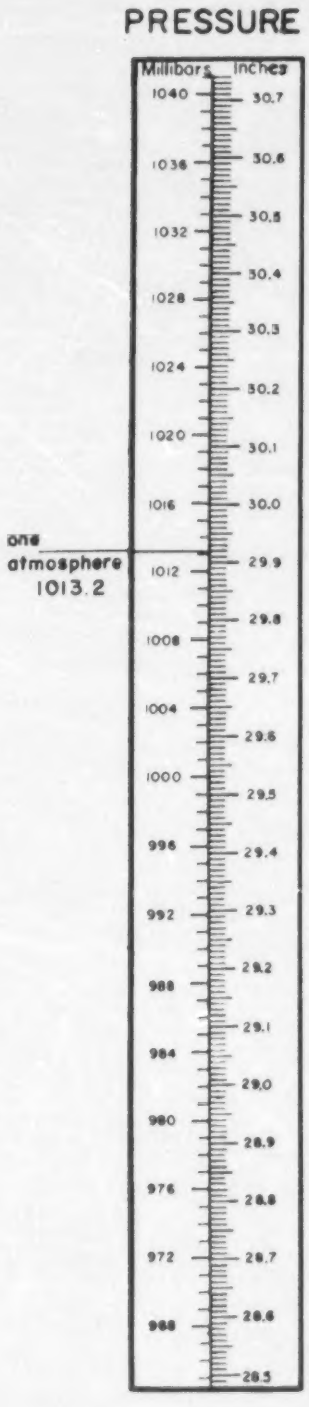
mP Maritime polar

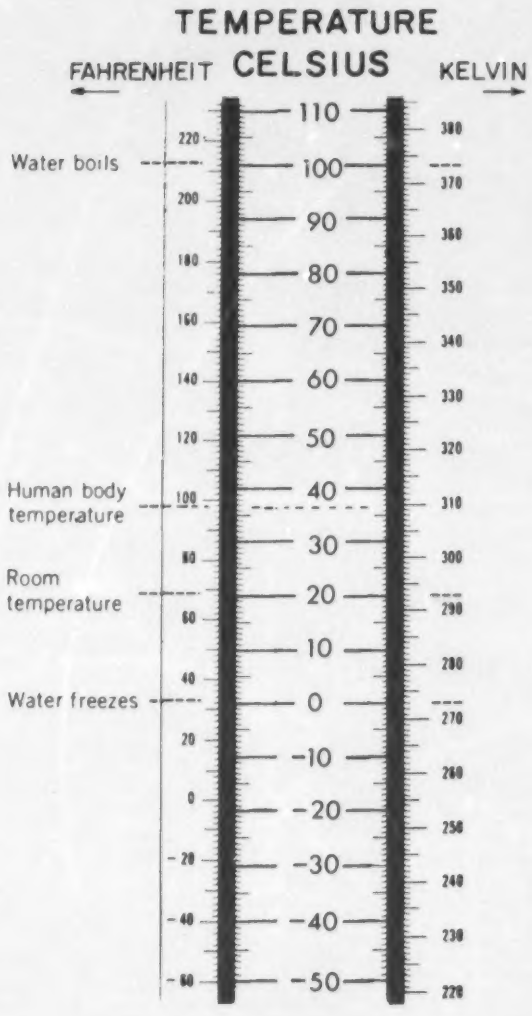
FRONT SYMBOLS



Present Weather SYMBOLS

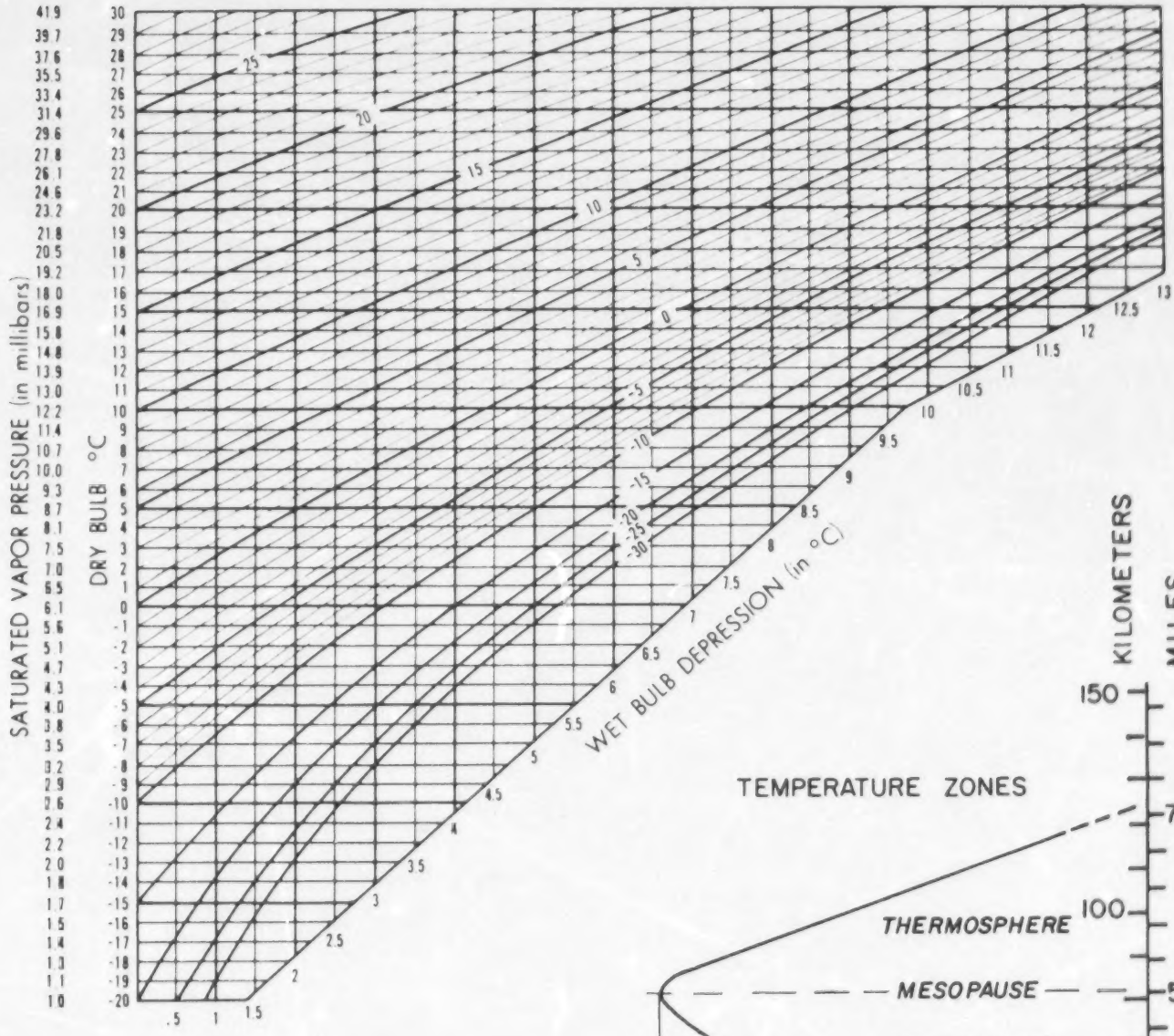
II PRESSURE – TEMPERATURE

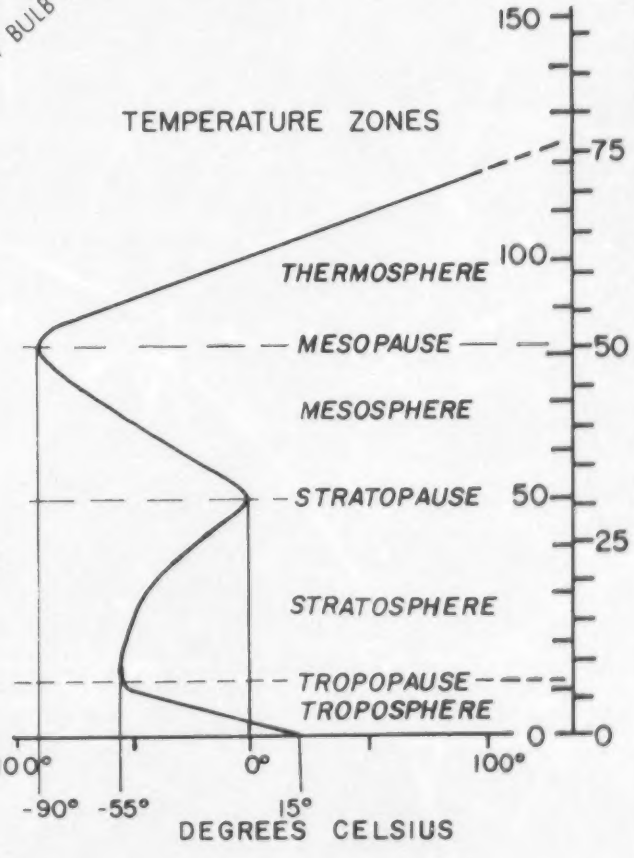




III PHYSICAL PROPERTIES OF THE ATMOSPHERE

DEWPOINT TEMPERATURE CHART

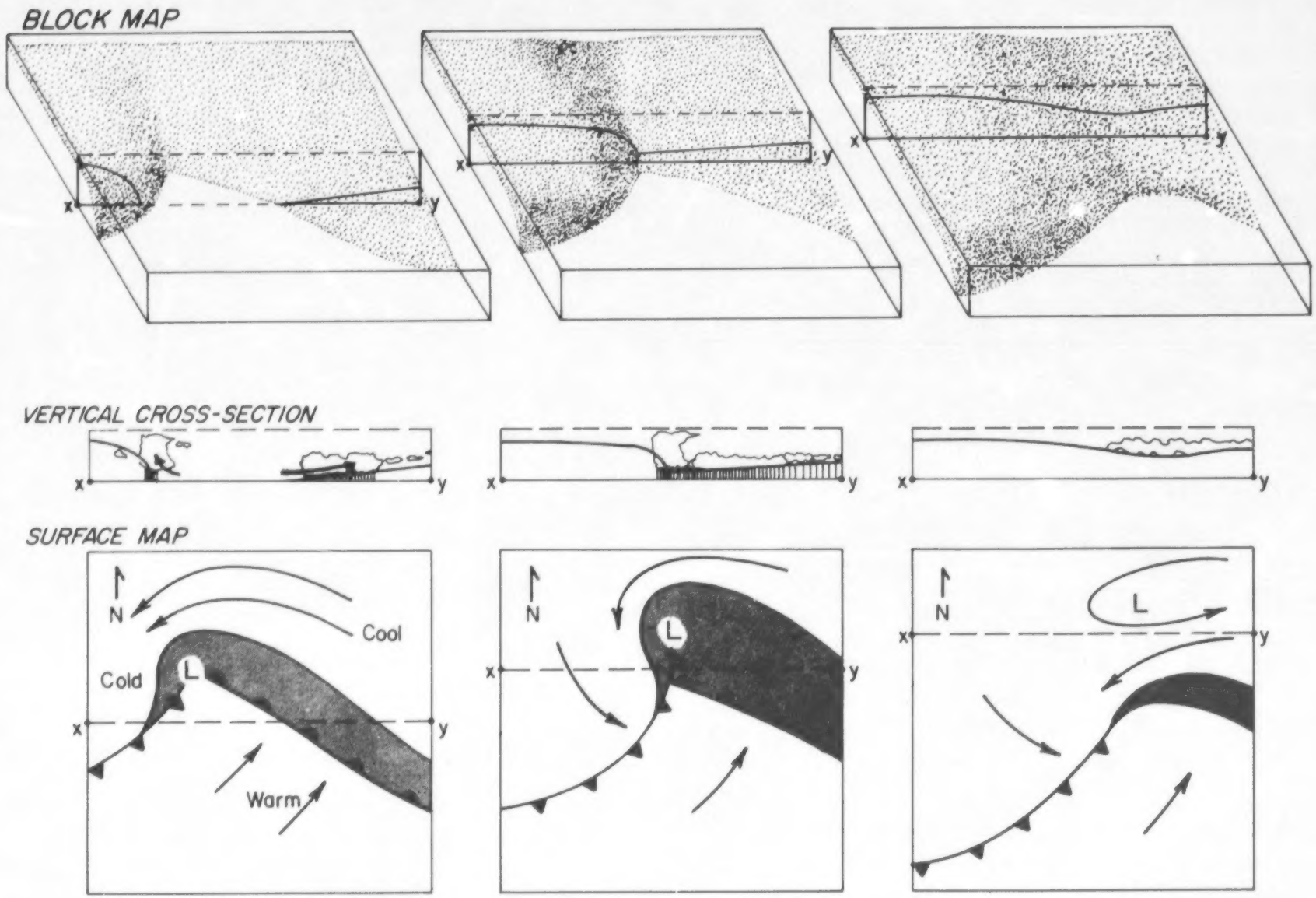




Relative Humidity Formula

$$RH(\%) = \frac{\text{vapor pressure of dewpoint temp.}}{\text{vapor pressure of dry-bulb temp.}} \times 100$$

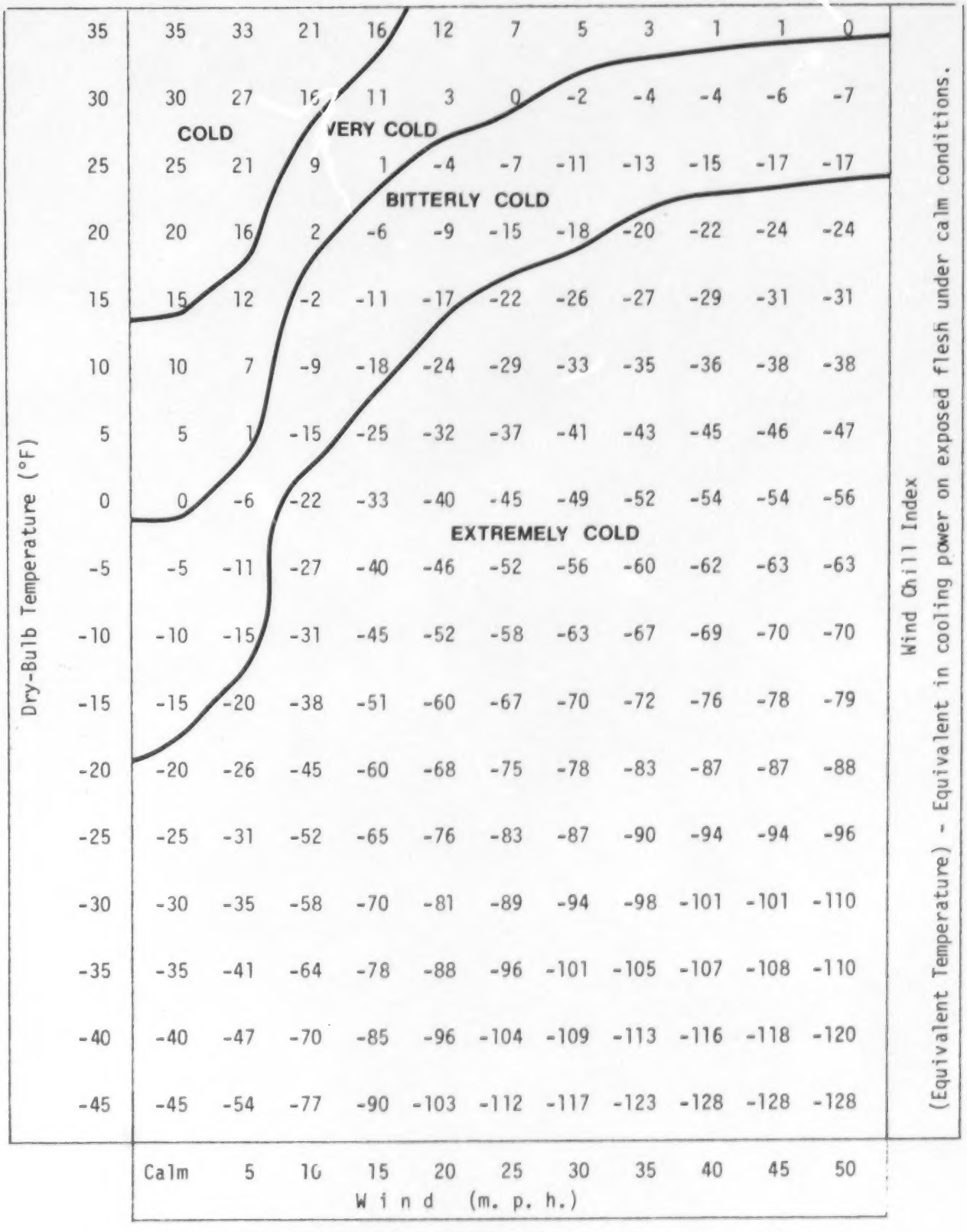
IV WAVE CYCLONE MODEL



V MODEL DATA SHEET FOR WEATHER WATCH

Date Time							
Air Temperature in °F	80						
	70						
	60						
	50						
	40						
	30						
	20						
	10						
Atmospheric Pressure in mb.	1040						
	1030						
	1020						
	1010						
	1000						
	900						
Wind direction, speed, and sky cond. Cloud type Weather							
Precip. in inches	0.5						
	0.3						
	0.1						

VI WIND CHILL TABLE



Dry-Bulb Temperature (°F)	Calm	5	10	15	20	25	30	35	40	45	50
35	35	33	21	16	12	7	5	3	1	1	0
30	30	27	16	11	3	0	-2	-4	-4	-6	-7
25	25	21	9	1	-4	-7	-11	-13	-15	-17	-17
20	20	16	2	-6	-9	-15	-18	-20	-22	-24	-24
15	15	12	-2	-11	-17	-22	-26	-27	-29	-31	-31
10	10	7	-9	-18	-24	-29	-33	-35	-36	-38	-38
5	5	1	-15	-25	-32	-37	-41	-43	-45	-46	-47
0	0	-6	-22	-33	-40	-45	-49	-52	-54	-54	-56
-5	-5	-11	-27	-40	-46	-52	-56	-60	-62	-63	-63
-10	-10	-15	-31	-45	-52	-58	-63	-67	-69	-70	-70
-15	-15	-20	-38	-51	-60	-67	-70	-72	-76	-78	-79
-20	-20	-26	-45	-60	-68	-75	-78	-83	-87	-87	-88
-25	-25	-31	-52	-65	-76	-83	-87	-90	-94	-94	-96
-30	-30	-35	-58	-70	-81	-89	-94	-98	-101	-101	-110
-35	-35	-41	-64	-78	-88	-96	-101	-105	-107	-108	-110
-40	-40	-47	-70	-85	-96	-104	-109	-113	-116	-118	-120
-45	-45	-54	-77	-90	-103	-112	-117	-123	-128	-128	-128

NOTE: Wind speeds greater than 40 mph have little chilling affect.

APPENDIX C - SUPPLEMENTAL INFORMATION FOR TEACHERS

I Weather and Weather Systems

Weather deals with the short-term variations of the atmosphere. It arises from the unequal distribution of energy in the Earth's ocean of air. Variations in the amount of sunlight received around the globe produce uneven heating of the earth's land and water surfaces, and the air above. The resulting differences in air density create unbalanced forces which put air into motion. Moving air works to equalize the distribution of the atmosphere's energy, a goal never fully realized.

In most places, this motion is altered by the Earth's rotation. Air moving over the spinning planet forms gigantic whirls within air masses and along their boundaries. Those circulations having high surface pressures in their centers are called *anticyclones*. *Cyclones*, possessing low central pressures, are found along and near air mass boundaries. These *Highs* and *Lows* are carried along by the large-scale upper air flow of the atmosphere in which they are embedded.

Weather Systems

Highs and Lows usually influence large geographical areas. These systems play major roles in producing the weather at any particular location in the middle latitudes. Daily and seasonal factors act to change these large-scale systems. Local factors, including topography, proximity to sizable bodies of water, and acts of humans can modify the impacts of large-scale atmospheric systems on the weather we see.

Highs and Lows tend to move across the Earth, carrying with them certain general characteristics. Air tends to sink in Highs, producing clear skies and fair weather. However, not all weather in Highs is fair. There are times and places when air within Highs is pushed up. If heated or if sufficient water vapor is added from below, air may rise to form clouds and precipitation. Air in Highs can also be forced upward by hills and mountains to produce stormy weather.

Air tends to move upward in Lows, causing cloudiness and stormy weather. The interaction of air masses - the warm and cold sectors in the Low - give great variety in weather conditions. Nearly anything from just clouds to drizzle, blizzards, thunderstorms, and tornadoes is possible with low pressure systems.

It is these weather systems and their related features that appear on surface weather maps.

II Weather Models

Descriptive Models

Models provide frameworks for comprehending and evaluating information. Simple descriptive models applied to the atmosphere can help the beginning weather watcher to explain existing conditions and to attempt scientifically

based weather predictions. A person equipped with the most basic of atmospheric models can begin to make sense out of the weather. With the availability of both A.M. WEATHER and local weather information, models make it possible to relate direct observations to the broad-scale weather picture. Meteorologists use descriptive models in their work. They also use numerical models which are programmed on highly sophisticated computers.

Model Highs

A great deal of the weather we experience is determined by air masses in which temperatures and water vapor vary gradually in the horizontal over large regions. Air masses form when air resides for days or weeks over an extensive land or water surface possessing relatively uniform temperatures. With time, the air assumes the temperature and humidity characteristics of the underlying surface. Air above cold land surfaces becomes cold and dry. Central Canada is one place where such cold air masses are born. Air over warm water surfaces, such as in the Gulf of Mexico, can develop into warm moist air masses.

Sooner or later, air masses move from their source regions. As they move, they carry their temperatures and water vapor contents with them. There are a number of source regions for the air masses which migrate over the United States. Some regions produce more air masses than others. Air masses from a particular source region are likely to influence our weather more at one time of the year than at another. Air masses are modified as they migrate from their source regions and interact with new land and water surfaces.

Moving air masses exhibit high surface pressures at their centers so the Highs seen on weather maps frequently mark their presence. The circulation around these centers is anticyclonic, that is, clockwise as seen from above in the Northern Hemisphere. The air in the system is generally sinking and tends to produce clear skies and fair weather. The characteristic air mass properties (temperature, pressure, and moisture) and anticyclonic circulation provide the basis for a model of the High.

Model Wave Cyclones (Lows)

In the fluid atmosphere, air masses come in contact with one another. But they do not readily mix when composed of air with different densities. The colder and drier the air, the heavier it is. The warmer and more humid the air, the lighter it is. When unlike air masses come together, the boundaries separating them tend to remain distinct. These boundaries are called fronts. When not moving, they are called stationary fronts. When they move so that warmer air replaces colder air, they are warm fronts. Cold fronts occur when cold air moves over a region and replaces the warm air previously there.

Waves sometimes form along air mass boundaries as cyclonic circulations and centers of low pressure appear. A *wave cyclone* or *Low* is born and, depending on conditions aloft, may grow into a large-scale storm system similar to those that often affect our weather.

In wave cyclones, the air of neighboring air masses forms adjacent regions of relatively warm and cold air. These sectors are bounded by warm and cold fronts. The fronts and air sweep in counterclockwise motions around the

deepening low pressure centers. Air is pushed upward in the regions of the fronts to produce clouds and precipitation. The diagrams appearing in Appendix B IV provide views of a model wave cyclone at different stages.

Wave cyclones may be viewed as having life histories. The wave begins as cold air pushes forward in some places and retreats in others. Pressure at the center drops as the advancing cold front overtakes the slower-moving warm front to form an occluded front. The occlusion process leads to the eventual demise of the storm system. The cyclone, in its final stage, weakens to a faint whirl as traces of the occluded front disappear. Elsewhere, along the persistent air mass boundary, another wave cyclone comes into existence and it is destined to undergo a fate similar to that of its predecessor.

Computer Weather Models

While meteorologists use descriptive models, it must be mentioned that modern weather forecasting depends a great deal on numerical models. These models use the basic equations of physics - the conservation of energy, Newton's Laws of Motion - and the effects of solar and terrestrial radiation to forecast the weather. These are put in equation form and solved on computers. Since they simulate the future course of the weather numerically, they are called computer problems. The output of these computer problems provides guidance which is interpreted by the weather forecasters' National Weather Service maps seen on television and in newspapers depicting future conditions are actually computor-generated.

Classroom Use

It is suggested the chart appearing in Appendix B showing the wave cyclone model be duplicated and given to students. The block diagrams and vertical cross-sections are provided to show the three dimensional aspects of wave cyclones in the atmosphere.

Students should be asked to imagine they are moving through the model from right to left (from east to west) along lines drawn through the model. They should attempt to describe the changes in their weather as they travel through the system.

Drawings of model Highs and Lows on overhead transparencies can also be used to provide learning experiences. Lay a transparency with an outline drawing of northeastern U.S. on the overhead projector. Move the transparency with the model drawn on it across the map to simulate eastward movement. Have students describe weather changes as the systems move across their location on the map. This technique can be applied to transparency drawings of current weather maps to demonstrate persistence forecasting.

III Satellite Images

When we were first able to see satellite pictures of cloud patterns, one meteorologist claimed that they radically changed his image of how the atmosphere worked. With these pictures, we see the actual patterns of clouds, the comma-like cloud masses associated with Lows and the squall lines that can produce devastation from the sky. We can see motion in them

with pictures made every half hour and gain better understanding of the movement of weather systems. Infrared imagery has added more information allowing us to measure temperatures of the land, oceans, and clouds (within certain errors). This has helped fill gaps in the data over the oceans and sparsely populated areas. The detection and surveillance of hazardous weather conditions (especially hurricanes) are major benefits arising from the use of weather satellites.

Images are produced by a process in which sensors aboard satellites scan a segment of our planet's surface, then reduce the information to line patterns "seen" at various wavelengths. These are transmitted to receiving stations where they are accumulated line by line to build a picture of the view from space.

Satellites supply visible light and infrared images. Pictures based on visible light reflected from Earth currently have resolutions as small as one-half mile. Infrared images are derived from the heat radiation emitted by the Earth, clouds, and the atmosphere itself, and have resolutions down to 4 miles.

Weather satellites providing the imagery usually seen on television and in newspapers are located in geostationary orbits some 23,000 miles in space above South America and the Pacific Ocean. Each satellite remains above the same point above the equator, taking the same time to orbit the planet as the Earth takes to make one rotation.

Visible and Infrared Imagery

There are advantages and disadvantages to both visible and infrared satellite imagery. Visible imagery can give greater detail because of its higher resolution and greater discrimination (differentiating between fog and surface features, for example). However, it is available only for daylit areas and it shows clouds on the daytime side of the Earth to be mostly white since they are good reflectors of sunlight. The major advantage of infrared is that it enables us to "see" at night. In the infrared picture, there are many shades of gray, since such imagery is really a representation of temperature. Cold temperatures appear white while warmer temperatures are displayed as varying shades of gray with the warmest being the darkest. High clouds with thick clouds underneath are cold and show as white in both the visible and infrared. Low clouds that are relatively warm show as white on the visible and gray on the infrared images, however, since infrared shows variations in temperatures it does not always distinguish low clouds and fog from the nearby earth surfaces of similar temperatures. Also, high, thin clouds are almost transparent in the visible and can appear warmer than their true temperatures in the infrared.

Satellite data can be treated to produce enhanced images for special uses. In the ordinary infrared view, the cold tops of clouds can appear bright, but we have no way of telling which tops are higher and therefore indicators of more severe weather. In the enhancement, ranges of temperature are assigned various shades of gray. Consequently, the coldest regions (the highest cloud tops) will stand out. The enhanced image with its greater contrasts shows at a glance where the more intense weather was probably located.

Visible and infrared images complement each other. Used in combination, they provide a much more complete picture of the atmosphere than would be possible otherwise.

Classroom Use

It is suggested that the teacher compile a file of satellite photos from whatever sources available along with surface weather maps for as near the same times as possible. Those showing wave cyclones, evidence of jet streams, hurricanes, thunderstorms, large air masses, etc., can be especially useful.

IV Hazardous Weather

Thunderstorms

It is estimated that, at any given moment, nearly two thousand thunderstorms are actively taking place on the Earth. Their frequency and potential for violence make them one of nature's great destroyers and killers.

Thunderstorms begin where warm, humid air is forced upward. This can be done by mechanical lifting when a wedge of dense air undercuts warm, moist air, or by the thermal lifting of moist air caused by the Sun's heating of the Earth's surface. As air rises, it expands and cools, and the water vapor it contains begins to condense into cloud droplets. Continued upward movement can produce the towering cumulonimbus or thunderstorm cloud. Once an individual thundercloud or cell reaches maturity, downdrafts, started by the pull of falling precipitation, begin to destroy it. Most thunderstorms are composed of several cells. Each of these lasts for perhaps twenty minutes before dissipating as the sometimes violent downdrafts bring about its collapse. New cells may form, replacing old ones, so some thunderstorms can last several hours or more. Individual cells may be several miles across at their bases and reach altitudes of eight miles or more.

Strong gusts of cold winds occur directly beneath many mature thunderstorm cells. Lightning always accompanies the thunderstorms. Hail, ranging from pea size to that of a baseball, and damaging straight-line winds sometimes occur and cause considerable damage. Flash floods (produced by heavy rains) and tornadoes may also be associated with thunderstorms. Flash floods, lightning, and tornadoes are major killers.

Thunderstorm Watches and Warnings

For the purpose of watches and warnings, severe thunderstorms are defined as those in which there are winds of more than 58 miles per hour or hail 3/4 inch or more in diameter.

Severe thunderstorm watches are issued whenever severe thunderstorms are possible. Severe thunderstorm warnings indicate severe thunderstorm conditions have been reported or indicated by radar.

Lightning

Lightning strikes our globe about a hundred times a second. It kills more than one hundred Americans each year. Annual property losses - fire and

other damage to structures, aircraft damage, livestock deaths and injuries, forest fires, and other effects - are estimated to be several $100 million.

Lightning is a huge electrical spark resulting from the separation of electrical charges in the thunderstorm. The accumulation of a large electrical charge in the lower portion of the cloud can induce the opposite charge on the Earth below. The air, a poor conductor of electricity, prevents a flow of current until very large electrical charges accumulate. When discharge occurs, it is along a lightning channel that typically connects elevated ground objects (such as buildings and trees) and the cloud base.

Flash Floods

Floods are a natural part of life along the rivers of our country. Some floods are seasonal, as when winter or spring rains and meling snows fill river basins with too much water, too quickly. Others are sudden, the result of heavy precipitation. These are *flash floods.* Moving at incredible speeds, the waters of flash floods can roll boulders, tear out trees, destroy buildings and bridges, and scour out new channels. Water levels can rise twenty feet or more above normal in minutes or less.

Flash floods occur in mountainous or hilly areas where thunderstorms can change trickling little brooks into raging treacherous torrents of water. In urban areas, heavy rains can overload human-made drainage channels to bring on flash flooding. They can also be created by ice-jam breakup or dam failure. Regardless of their cause, there is little time between the detection of flash flood conditions and the arrival of the flood crest. Swift action is essential to the protection of life and property.

Tornadoes

These are short-lived, severe local storms. Tornadoes are violently rotating columns of air often observable as funnel-shaped appendages to a thunderstorm cloud. The funnel is initially composed of condensed water vapor and is itself a cloud. However, when the circulation of the funnel reaches ground level, it usually picks up dust and debris, which eventually darkens the entire funnel. Tornadic damage can occur even when the visible condensation funnel cloud does not seem to reach the ground.

Tornadoes vary greatly in character. On the average, tornado paths are only a quarter of a mile wide and seldom more than 15 miles long. Tornadoes usually move from the south, southwest, or west at around 30 miles per hour (but they can move as fast as 60 miles per hour or more). They last for 15 minutes or less (although some last for hours). Their internal wind speeds range from about 75 miles per hour to probably well over 200 miles per hour. The longer-lived, larger, and faster-moving tornadoes are responsible for most deaths and the worst devastation.

Scientists believe the tornado begins within an intense thunderstorm and then develops downward to the Earth's surface. Not all thunderstorms will spawn tornadoes, but when the proper weather conditions are present (unseasonably warm and humid air at the earth's surface, cold air at middle atmospheric levels, and strong upper level jet stream winds), severe thunderstorms and tornadoes are more likely to occur.

Tornadoes have occurred in all 50 states but no area is more prone to their formation than the continental plains and Gulf coast of the U.S. They are observed most commonly in the warm part of the day, between noon and midnight. They can occur throughout the year, but April, May, and June are the months when they are of greatest frequency. December and January are when their numbers are lowest.

Hurricanes

These intense tropical cyclones are the greatest storms on Earth. Called *hurricanes* in our part of the world, *typhoons* in the western North Pacific and *cyclones* in the Indian Ocean, and South Western Pacific Ocean, the large revolving storms are accompanied by destructive winds with speeds of 74 miles per hour and higher, heavy rains, and high waves and tides. Winds may gust to more than 200 miles per hour. When a hurricane approaches land, a deadly storm surge can cause water to rise fifteen feet or more above normal tide heights, and push miles inland to cover low-lying areas.

Hurricanes are giant whirling systems in which air flows in a tightening spin around extremely low pressure centered in the storm's unique "eye." The eye, on the average about 15 miles across, is relatively free of clouds, with light winds and warm temperatures. Surrounding the eye is a circular-shaped region of towering clouds extending outward another twenty or thirty miles. It is here, in the eye wall, that the hurricane's maximum winds are found. Heavy cloud bands cover an area often several hundred miles in diameter. They spiral into the eye wall region, identifying the paths winds take to carry warm, humid air into the storm. These tropical cyclones, rotating counterclockwise in the Northern Hemisphere, can last several days or even weeks until they dissipate over land or colder water.

Hurricanes that strike our Gulf and Atlantic coasts are born in the tropical and subtropical North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. Often they begin as relatively small areas of thunderstorms which drift gradually to the west-northwest. Under certain conditions, these areas increase in size and intensity until they become full-fledged hurricanes. They move slowly in the tropics with forward speeds often less than 15 miles per hour. Their paths can be quite erratic, even forming loops. Eventually they turn northerly and finally toward the northeast as their forward motions increase. The six-month period from July 1 to November 30 is considered to be the Atlantic hurricane season although most occur in August through October. On average, six Atlantic hurricanes occur annually, although the number varies greatly from year to year.

Hurricane winds cause property damage, injuries, and deaths. They topple trees, demolish buildings, tear down power lines, and fill the air with wind-blown debris. But drowning is the major cause of hurricane deaths. As the storms approach and cross coastlines, they bring ashore mounds of water topped by huge, wind-blown waves. These storm surges are often 50 miles wide near the area where the hurricane eye makes landfall. They rush forward, smashing buildings, flooding lowlands, eroding beaches and barrier islands, undermining waterfront structures, and washing out highway and railroad beds. Torrential rains contribute to the flooding, and as the storms move and their winds diminish, floods become the major threat to life and property.

Winter Storms

Snow, low temperatures, winds, and freezing rain or drizzle are components of winter storms. Singly or in combination, they produce the hazardous events of winter weather.

Winter Storm Warnings

Ice Storm Warning: Significant, possibly damaging, ice accumulation is expected. Freezing rain (or drizzle) means precipitation is expected to freeze when it hits exposed surfaces.

Heavy Snow Warning: A snowfall of at least 4 inches in 12 hours or 6 inches in 24 hours is expected. (Heavy snow can mean lesser amounts where winter storms are less frequent.)

Blizzard Warning: Considerable falling and/or blowing snow and winds of at least 35 miles per hour are expected for several hours.

Severe Blizzard Warning: Considerable falling and/or blowing snow, winds of at least 35 miles per hour, and temperatures 10°F or lower are expected for several hours.

High Wind Warning: Winds of at least 40 miles per hour are expected for at least one hour. (In some areas, this means strong gusty winds occurring in shorter time periods.)

Wind Chill

Wind as well as temperature affects the rate at which the body loses heat. Wind chill adds to the cooling power of low air temperature. Refer to the chart in Appendix B VI to determine the wind chill temperature. For example, when the outside temperature is 0°F and the wind speed is 20 miles per hour, the rate of heat loss is equivalent to -40°F under near-calm conditions.

Classroom Use

Everyone in your classroom is likely to encounter hazardous weather at some time in the future. Knowledge and understandings about these threatening situations might save their lives. It is suggested that time be taken to emphasize the need for adequate hazardous weather preparedness and response at the individual, family, and community levels. Some aspects of hazardous weather preparedness and response might be explored as a joint, science-social studies learning experience.